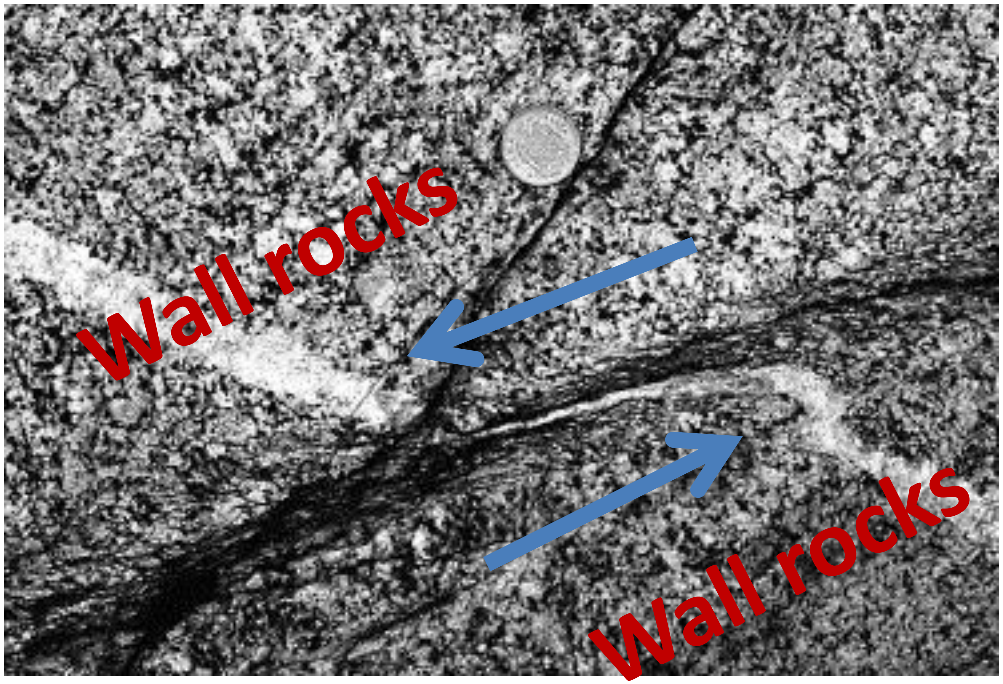
SHEAR ZONES

SHEAR ZONES



Carreras et al. (2005)

shear zone： a zone with concentrated deformations. Rocks in a shear zone are more highly deformed than rocks adjacent to the zone.

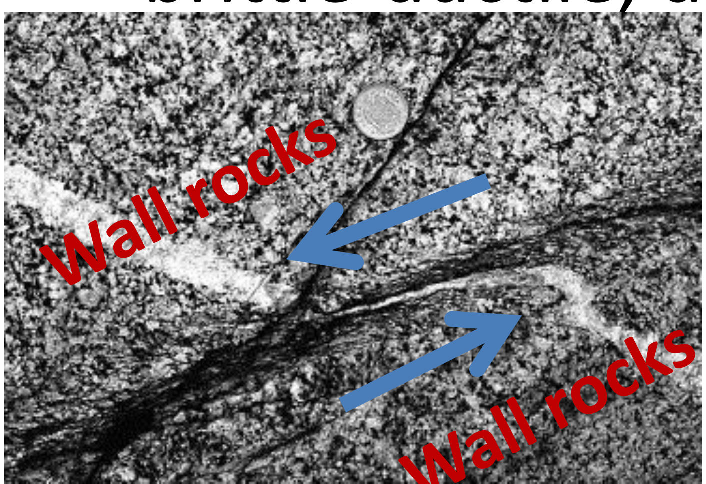
Rocks outside a shear zone (the **wall rock**) can be deformed or undeformed.

Outline

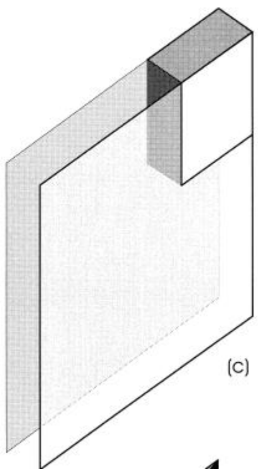
- Classification
- Rocks in shear zones
  - Particularly mylonites and dynamic recrystallization
- Deformation structures in shear zones
  - Foliations and Lineations
  - Porphyroclasts/porphyroblasts
  - Folds
- Shear sense indicator summary

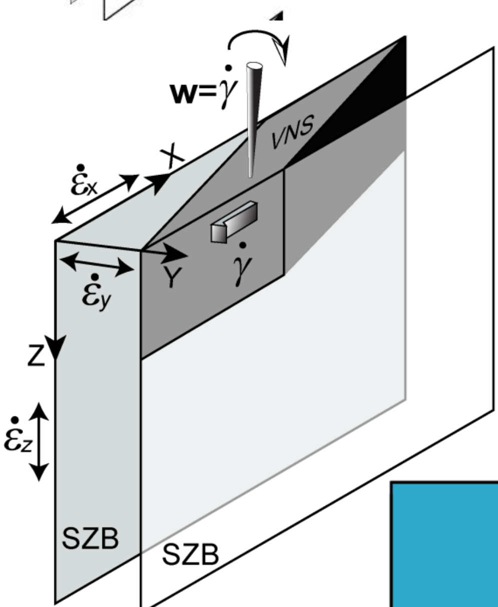
Classification of shear zones

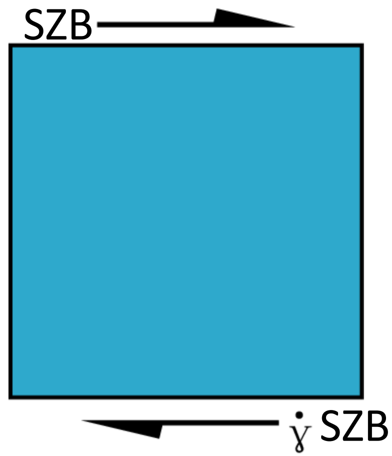
- Based on kinematics: (Simple/Pure/general) shear zone; transpressional shear zone or transtensional shear zone; monoclinic or triclinic
- Based on rock deformation behavior: Brittle, brittle-ductile, ductile



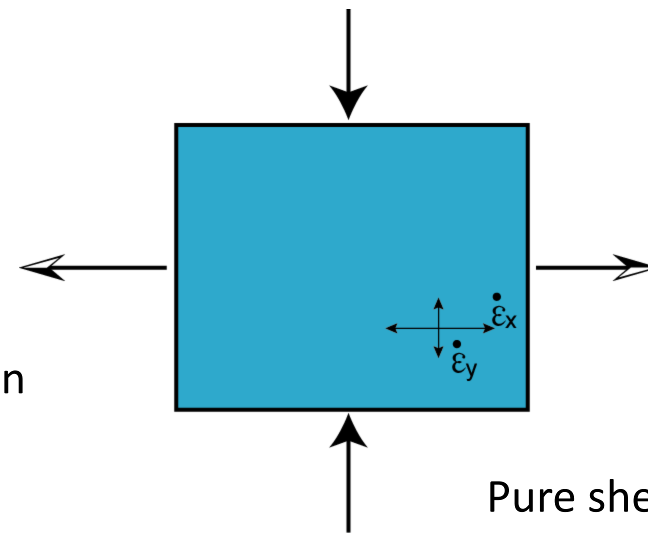
Classification I





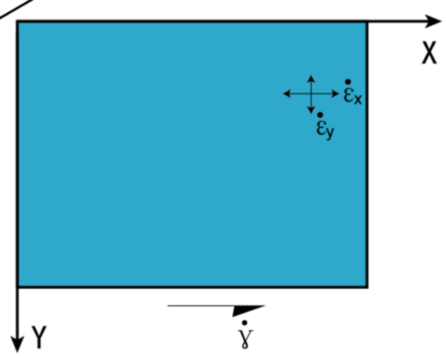


Simple shear
Non-coaxial deformation



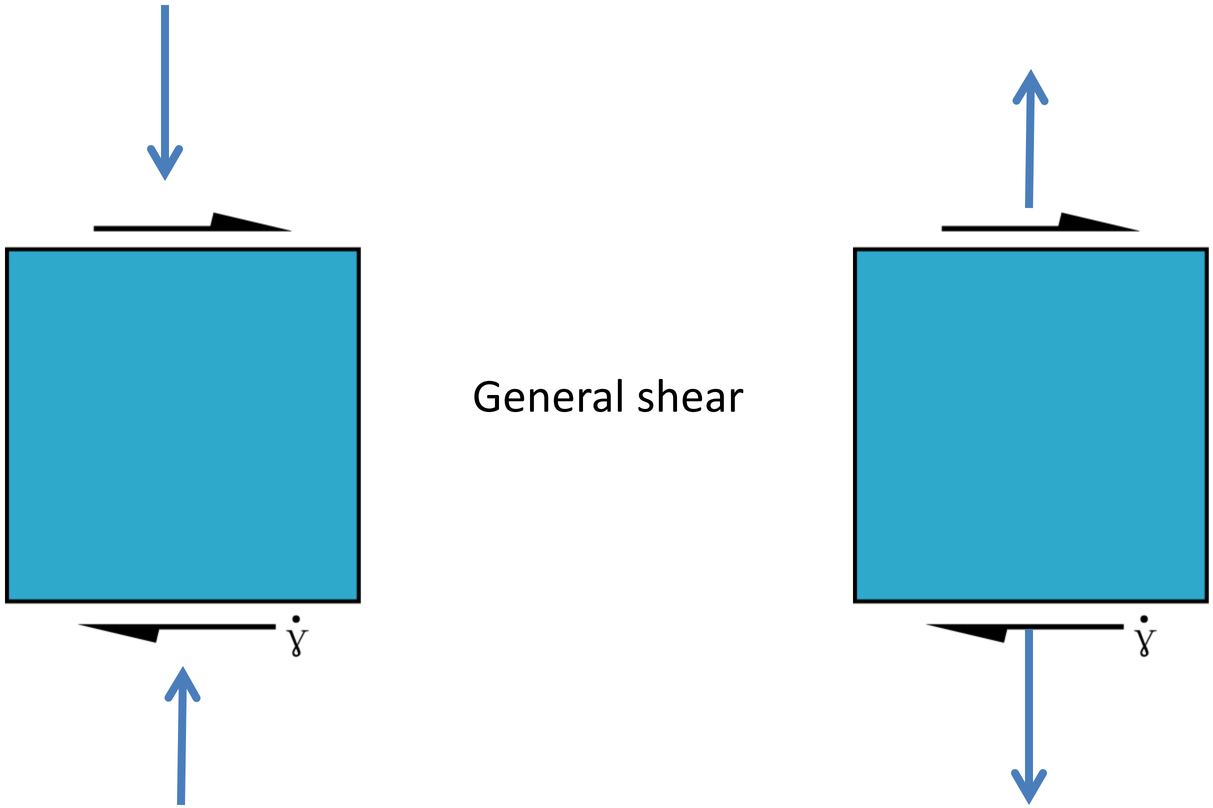
Pure shear

Coaxial deformation



General shear
Combination of simple shear and pure shear components
Non-coaxial deformation

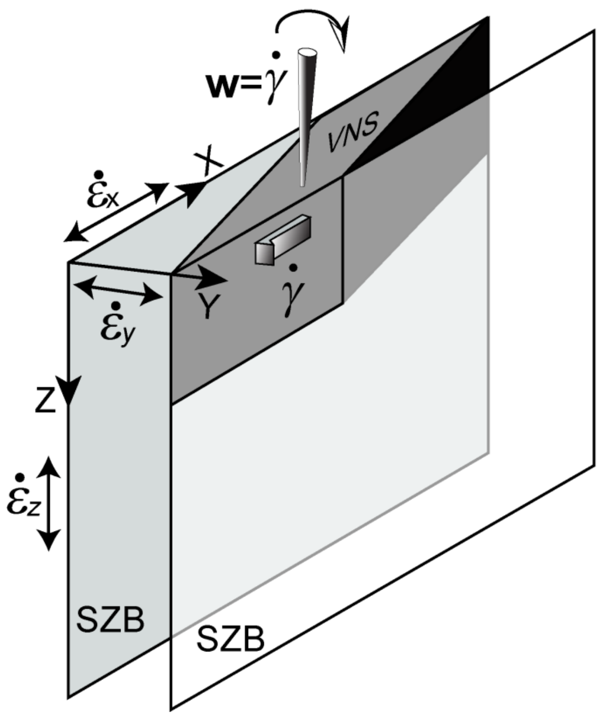
Classification I



Transpressional

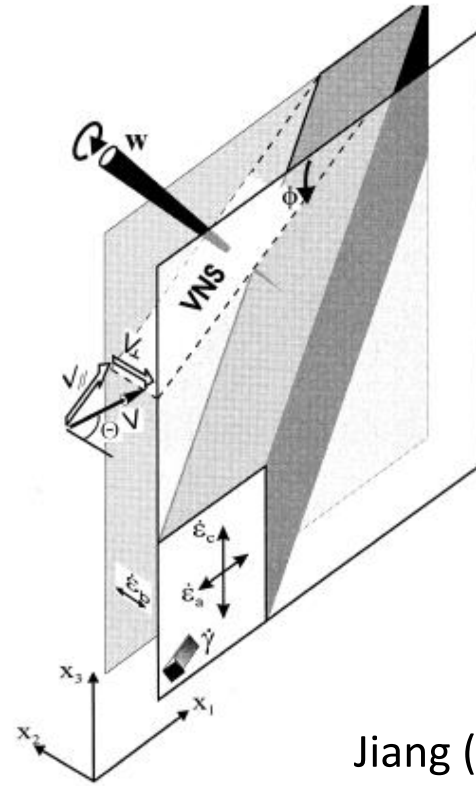
transtensional

Classification I



Monoclinic

Shear direction // one of the principal strain axes of the pure shear component



Jiang (1998)

Triclinic

Is a transpressional shear zone a monoclinic shear zone?

Classification II

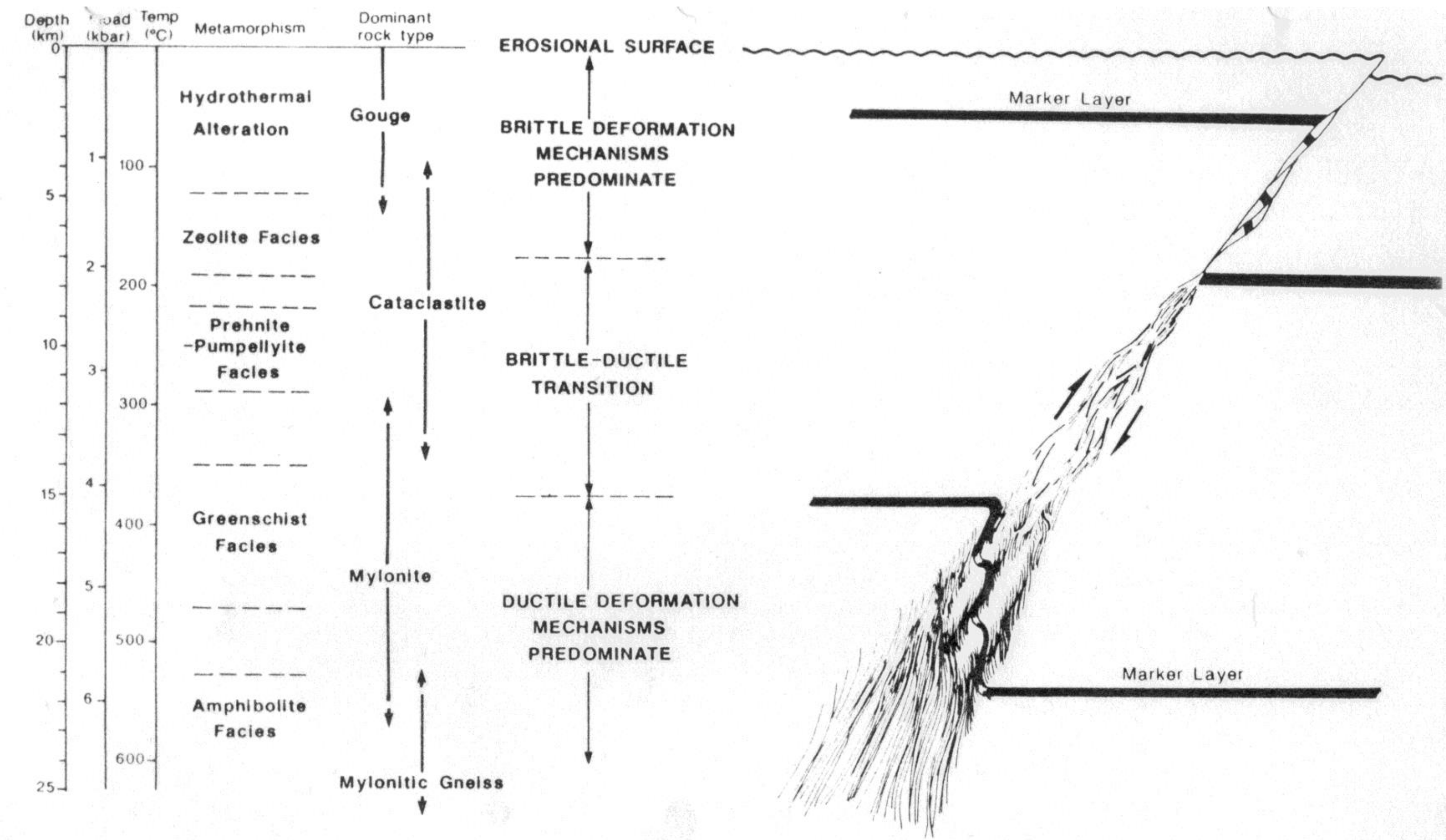
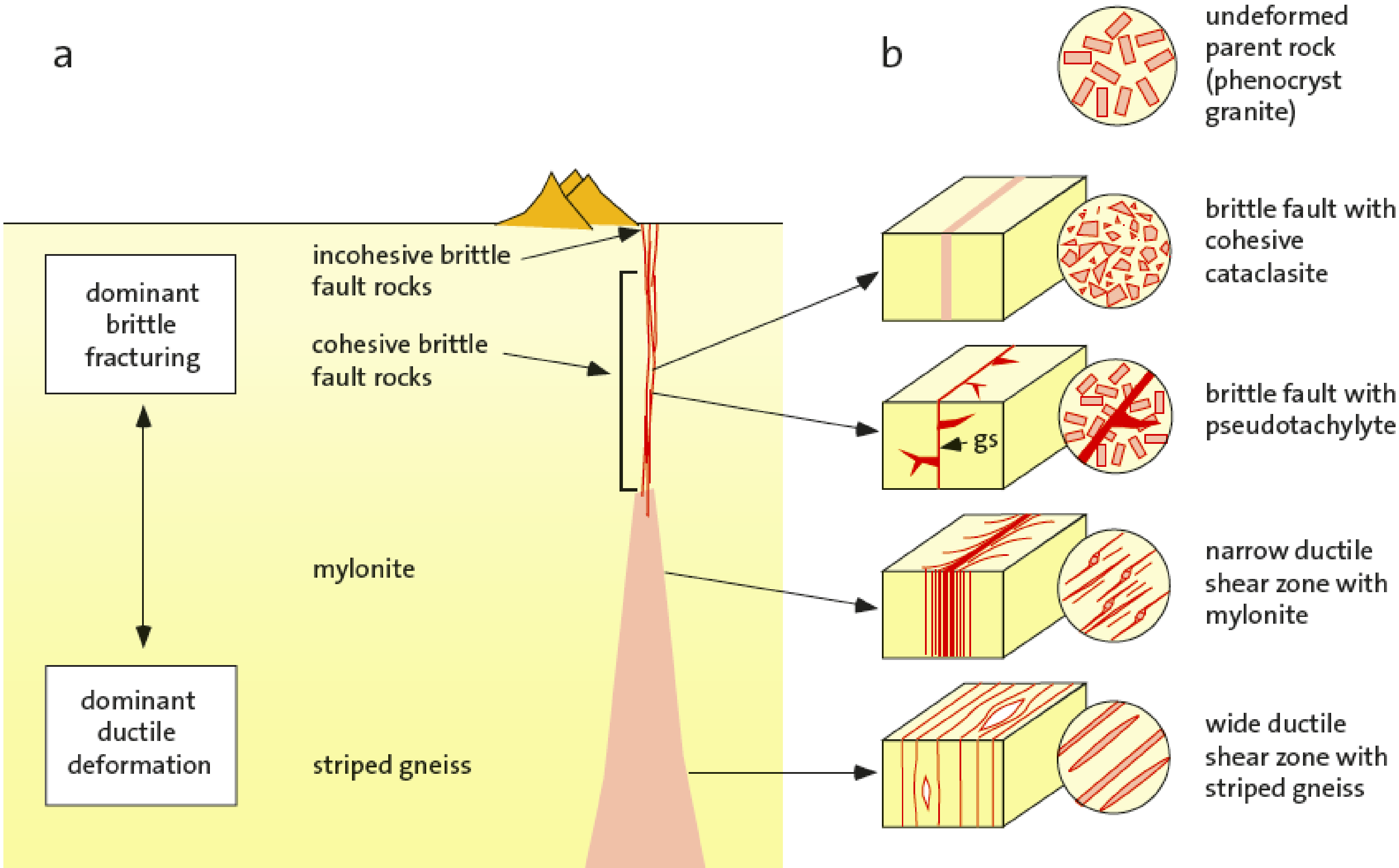


Figure 2.6. *Deformation regimes as a function of depth (modified from Simpson 1986, Sibson 1977, 1983).*

Distribution of the main types of fault rocks with depth in the crust



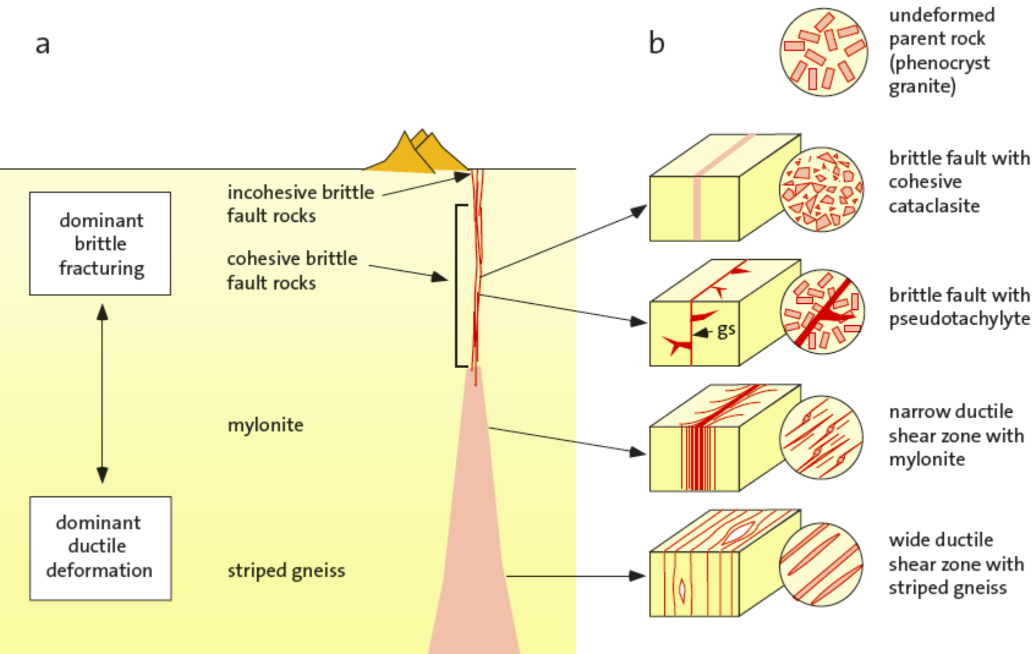
Passchier and Trouw (2006)

Classification of rocks in shear zone

In brittle shear zone (fault)

Incohesive fault rocks: incohesive breccia (>30% fragments), incohesive cataclasite (<30 fragments), fault gouge (few fragments)

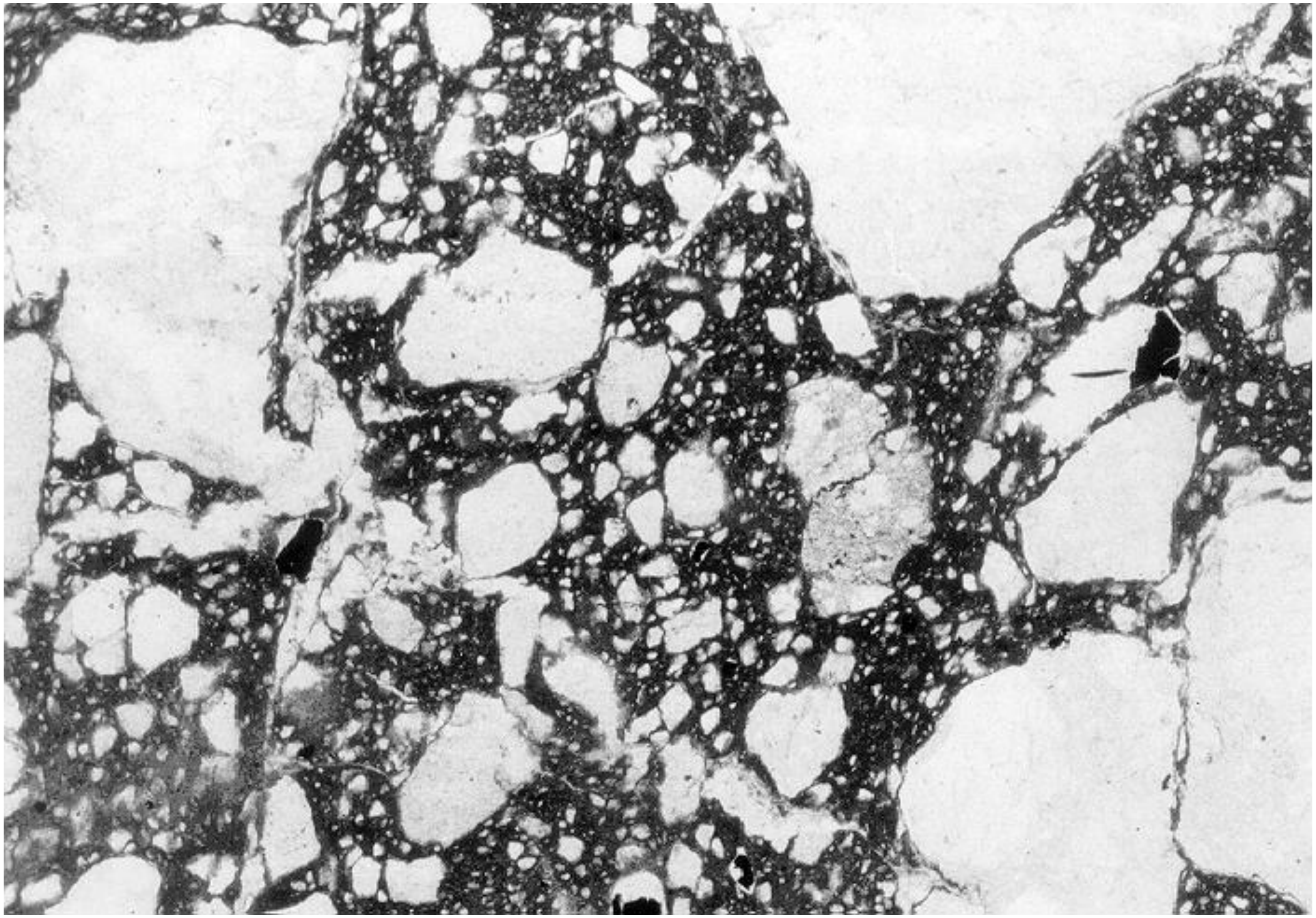
Cohesive fault rocks (due to precipitation of minerals; cement grains together): breccia, cataclasite, pseudotachylite



In ductile shear zones

Protomylonite (10-50% matrix), mylonite (50-90% matrix), ultramylonite (>90% matrix), blastomylonite (with significant static recrystallization), phyllonite (small-mica-rich mylonite; phyllitic appearance)

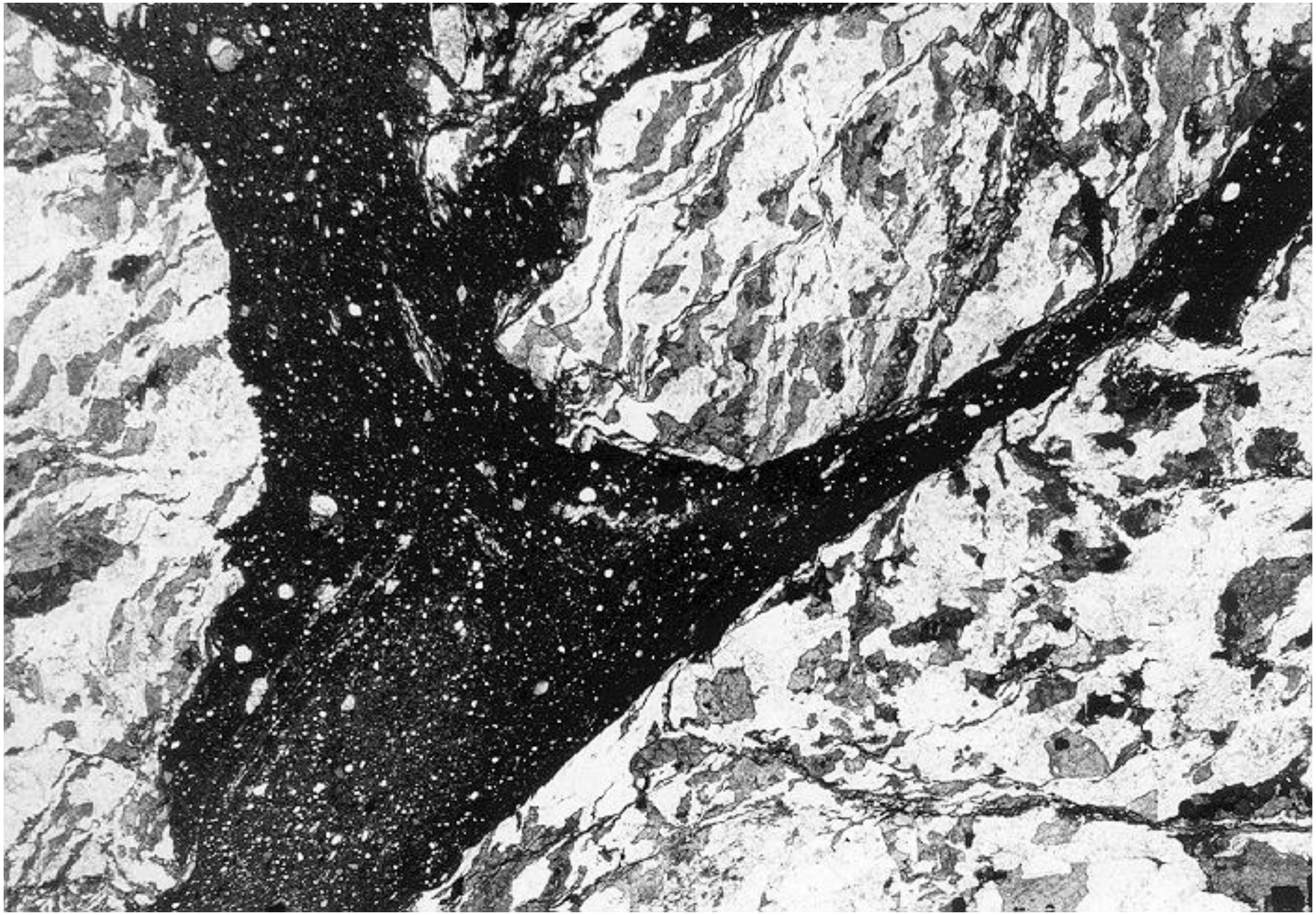
Cohesive fault breccia in quartzite



Passchier and Trouw (2006) PPL

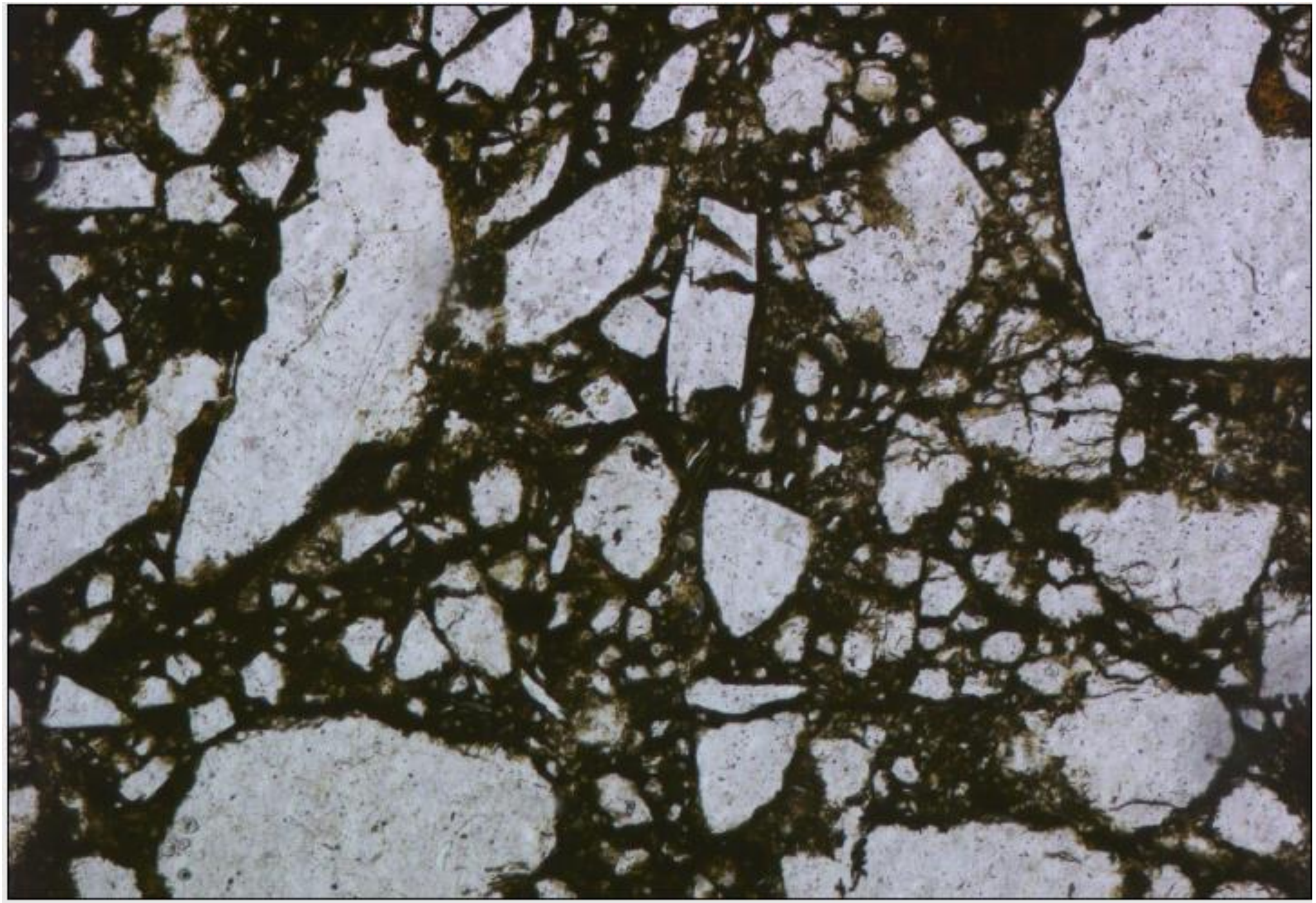
How do you tell it from conglomerate and diamictite?

Pseudotachylite in a foliated amphibolite



Passchier and Trouw (2006) Width of view 14 mm. PPL

Heat generated from rapid frictional sliding, grinding; melt; Cool down quickly, not crystal



Rock fragments in the matrix of iron oxide

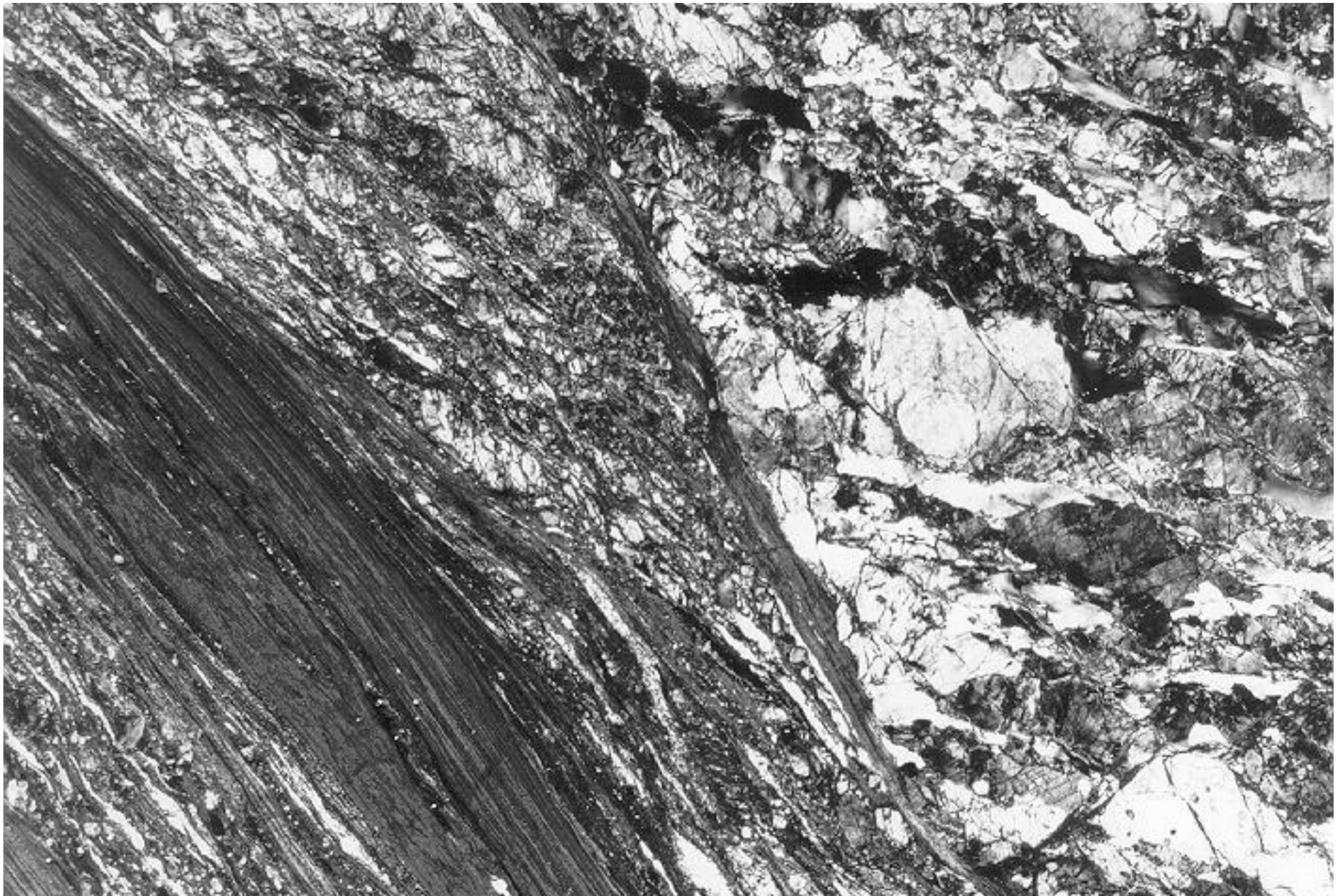
Passchier and Trouw (2006)

Cohesive Breccia/Cataclasites

These rocks are usually composed of angular broken rock fragments embedded in a matrix of quartz, iron oxide, calcite, chlorite and/or other minerals that precipitated from a fluid.

- approximately in the upper 10 km of the Earths crust, with lithostatic pressure up to about 3 kbar and temperatures up to about 300 °C

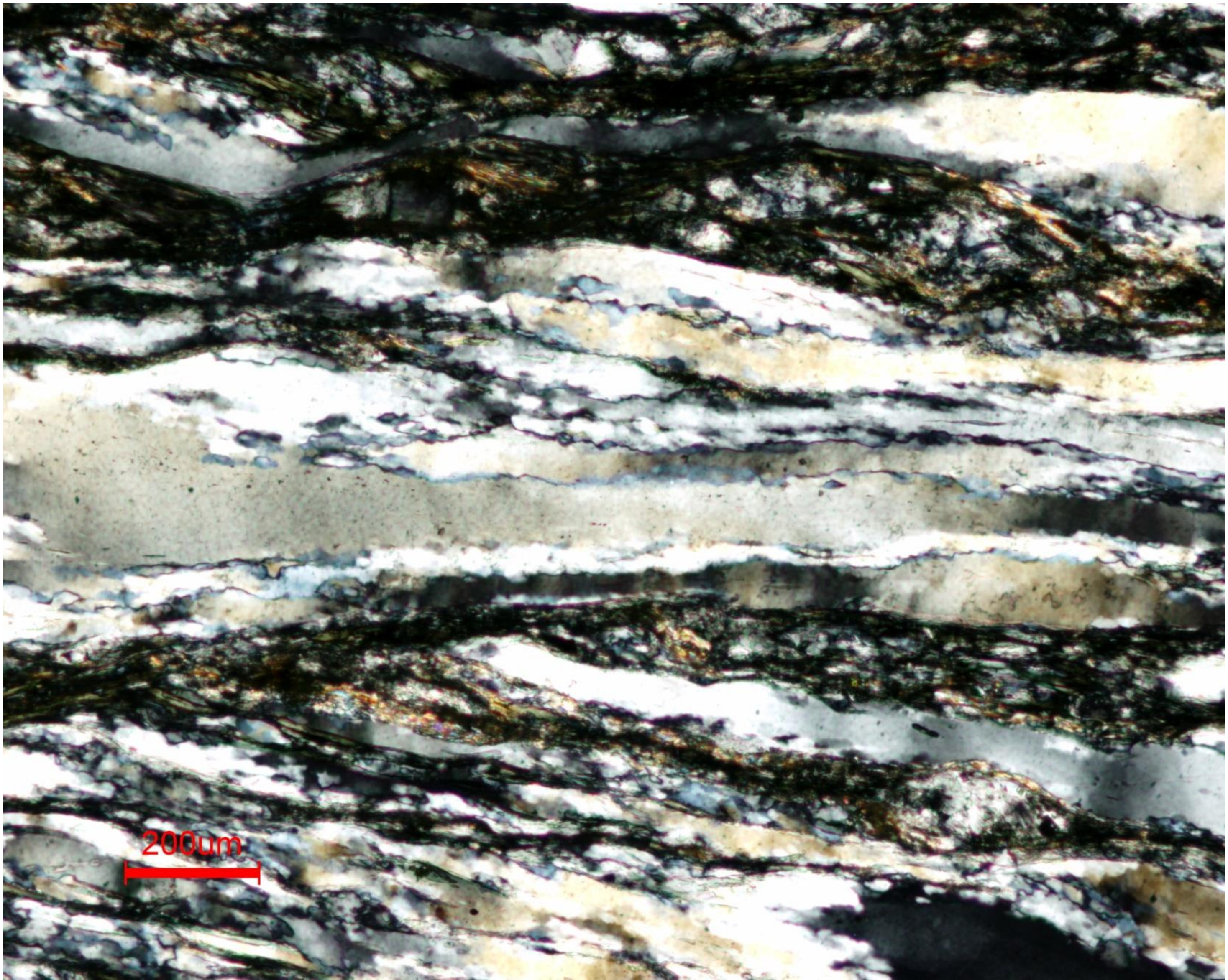
Protomylonite, mylonite and ultramylonite



Passchier and Trouw (2006)

The process for producing mylonite is characterized by grain size reduction.

Mylonitic rocks: Grain size reduction



Protomylonite?
Mylonite?
Ultramylonite?

Quartz ribbon;

Small quart grains around ribbon: Dynamic recrystallized quartz

Crystal defects: the agents of deformation

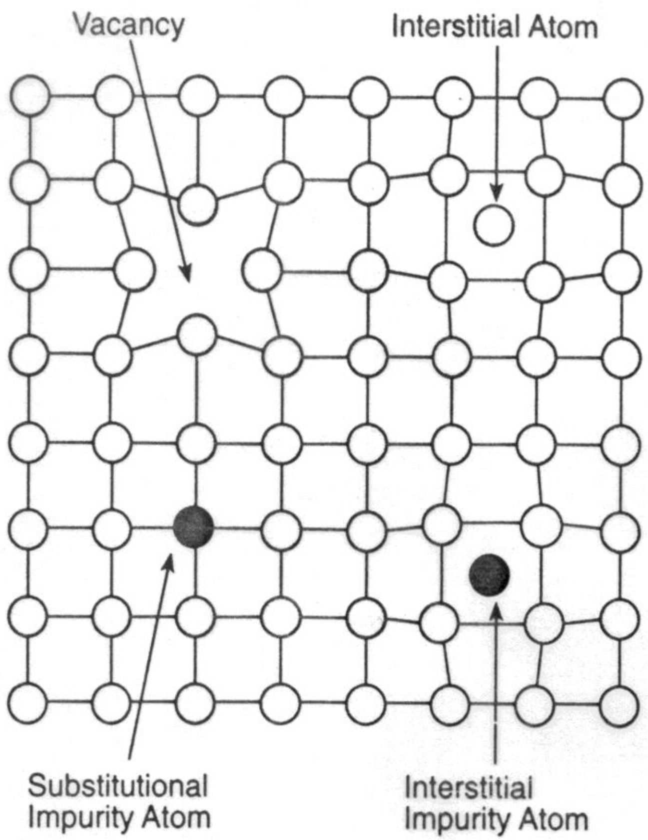


Figure 4.10 Various types of point defects within a crystal.

1. Zero dimensional or point defects: Vacancies, interstitials, etc.
2. On dimensional or line defects: Dislocations
3. Two dimensional or planar defects: Grain boundaries

Grain-boundary dislocations

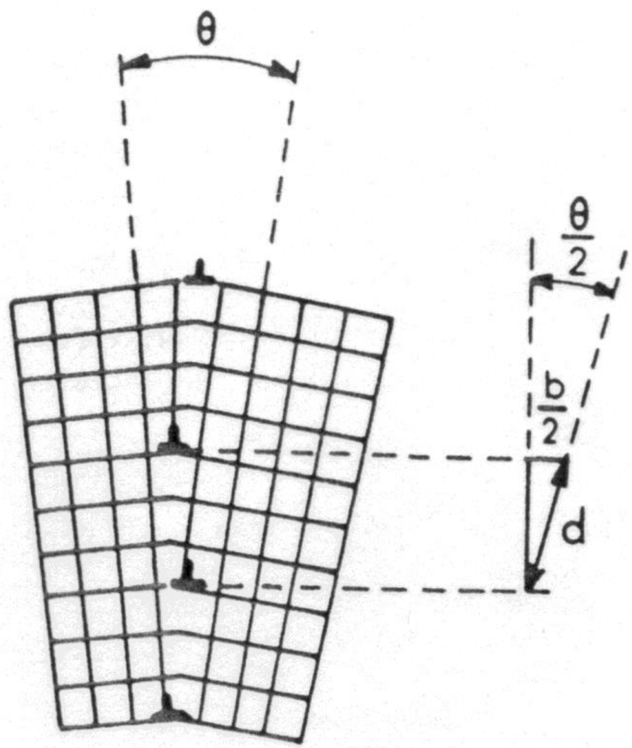


Fig. 3.40. Symmetrical edge dislocations tilt wall separating two subgrains misoriented by an angle θ

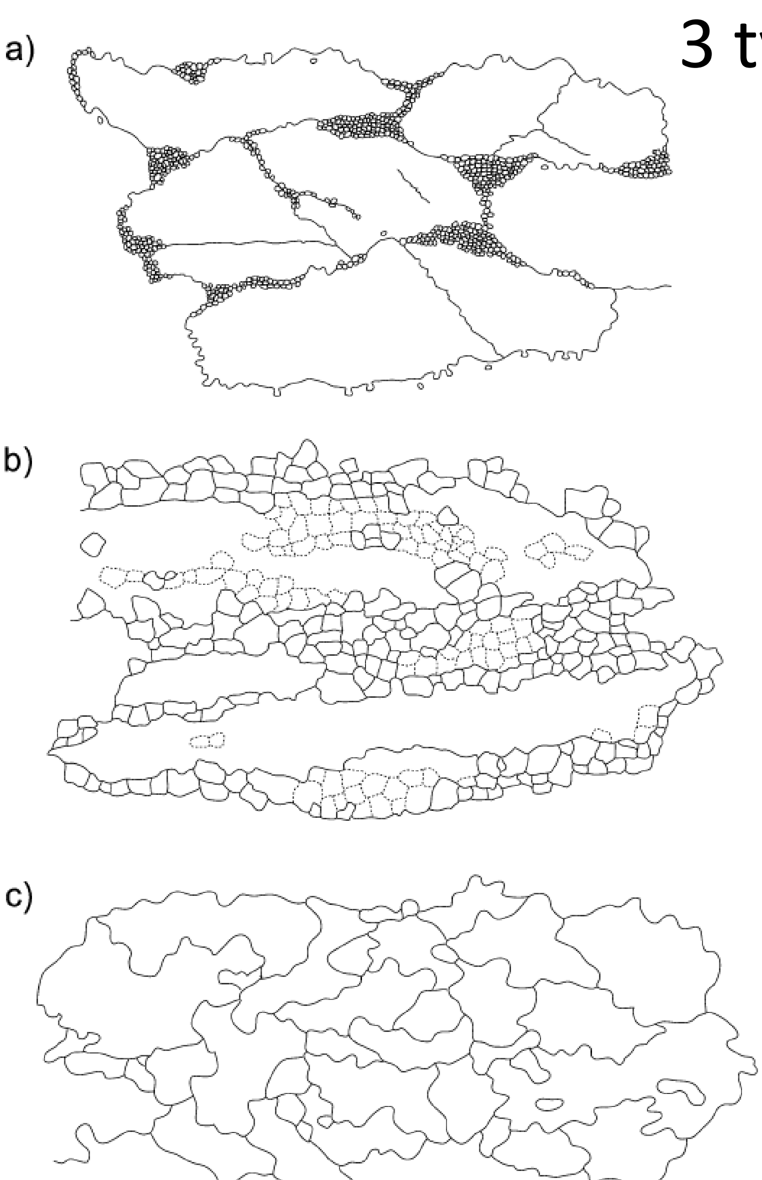
Low-angle boundary (subgrain boundary)

High-angle boundary (grain boundary)

Subgrains of quartz

Passchier and Trouw (2006)

3 types of dynamic recrystallization



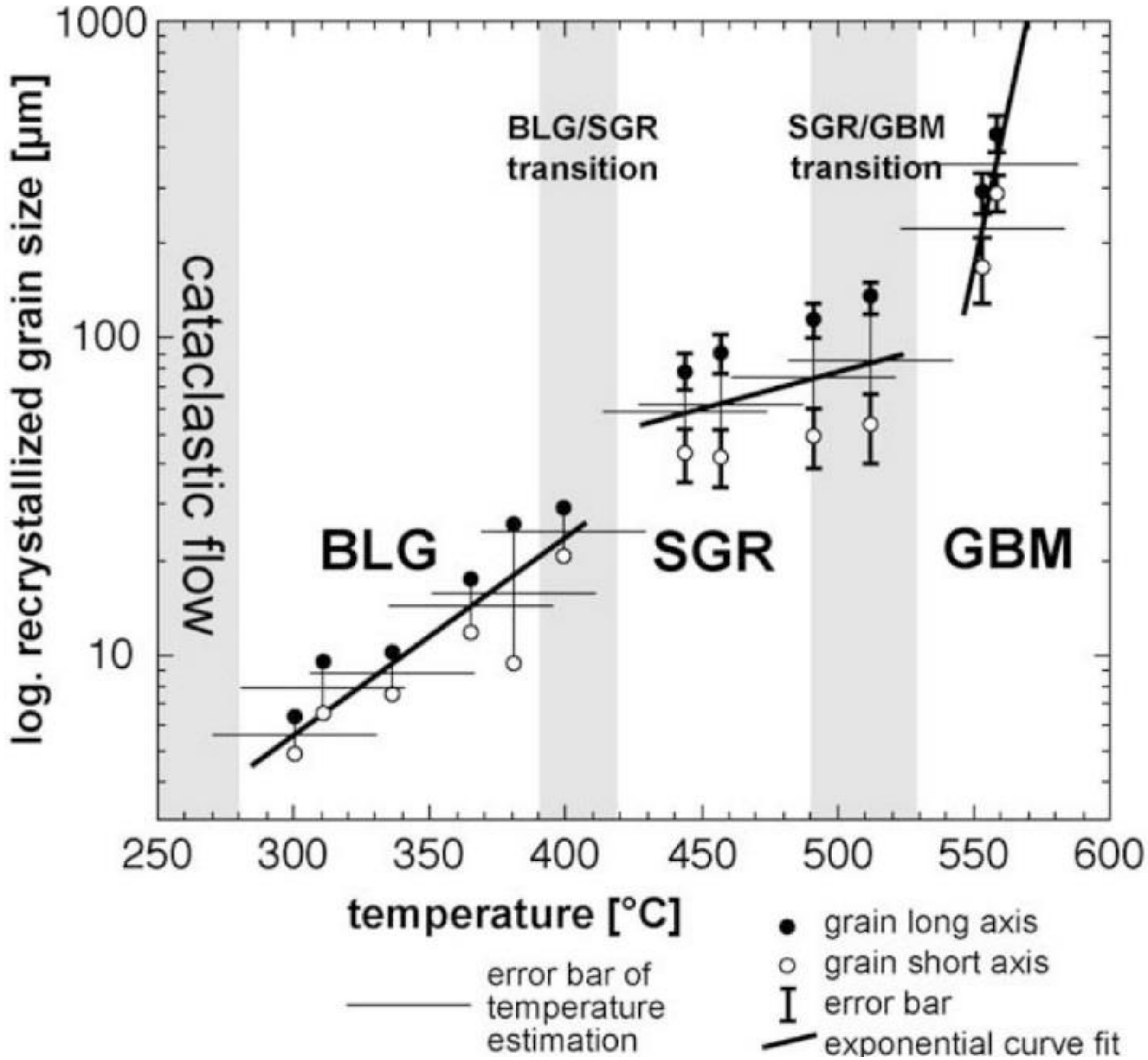
Stipp et al. (2002)

BLG: Bulging recrystallization

SGR: Subgrain rotation recrystallization

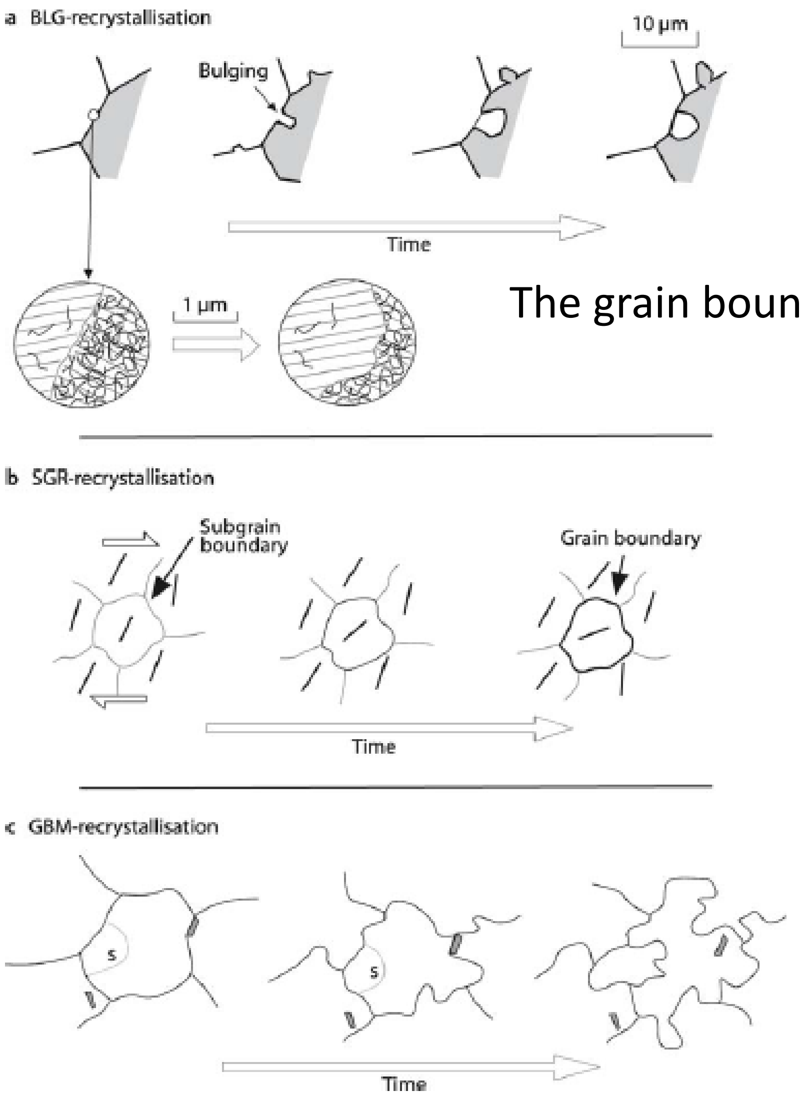
GBM: Grain boundary migration crystallization

Deformation temperature and dynamically recrystallized quartz grains



Stipp et al. (2002)

Dynamically recrystallized quartz grains



Passchier and Trouw (2006)

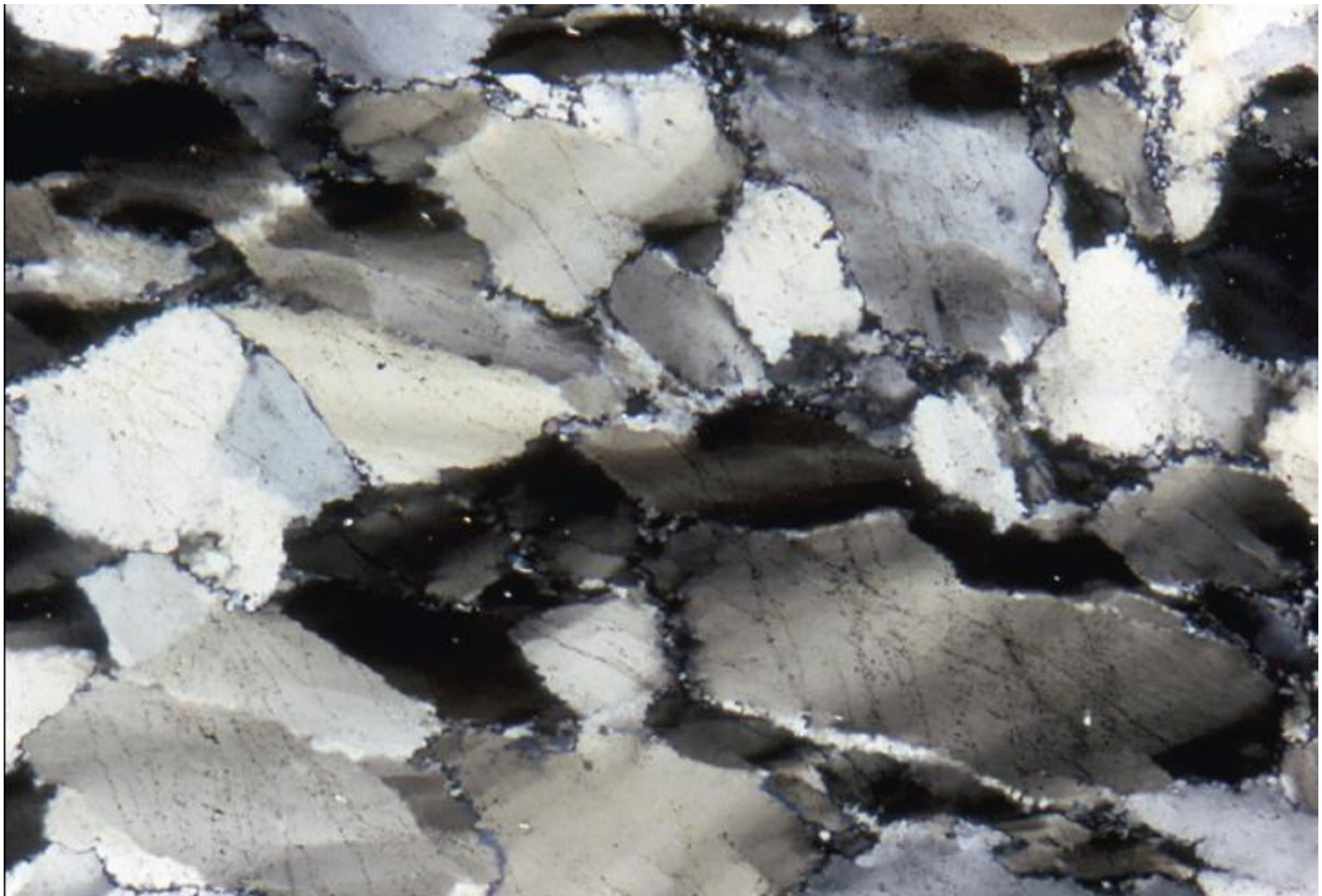
- Small grains around large grains.

The grain boundary bulges into the area with high dislocation density.

- If have inclusions, inclusions are rotated. Under CPL, boundaries are not clear.

- Interfingering sutures. Inclusions are not rotated. Larger grain size

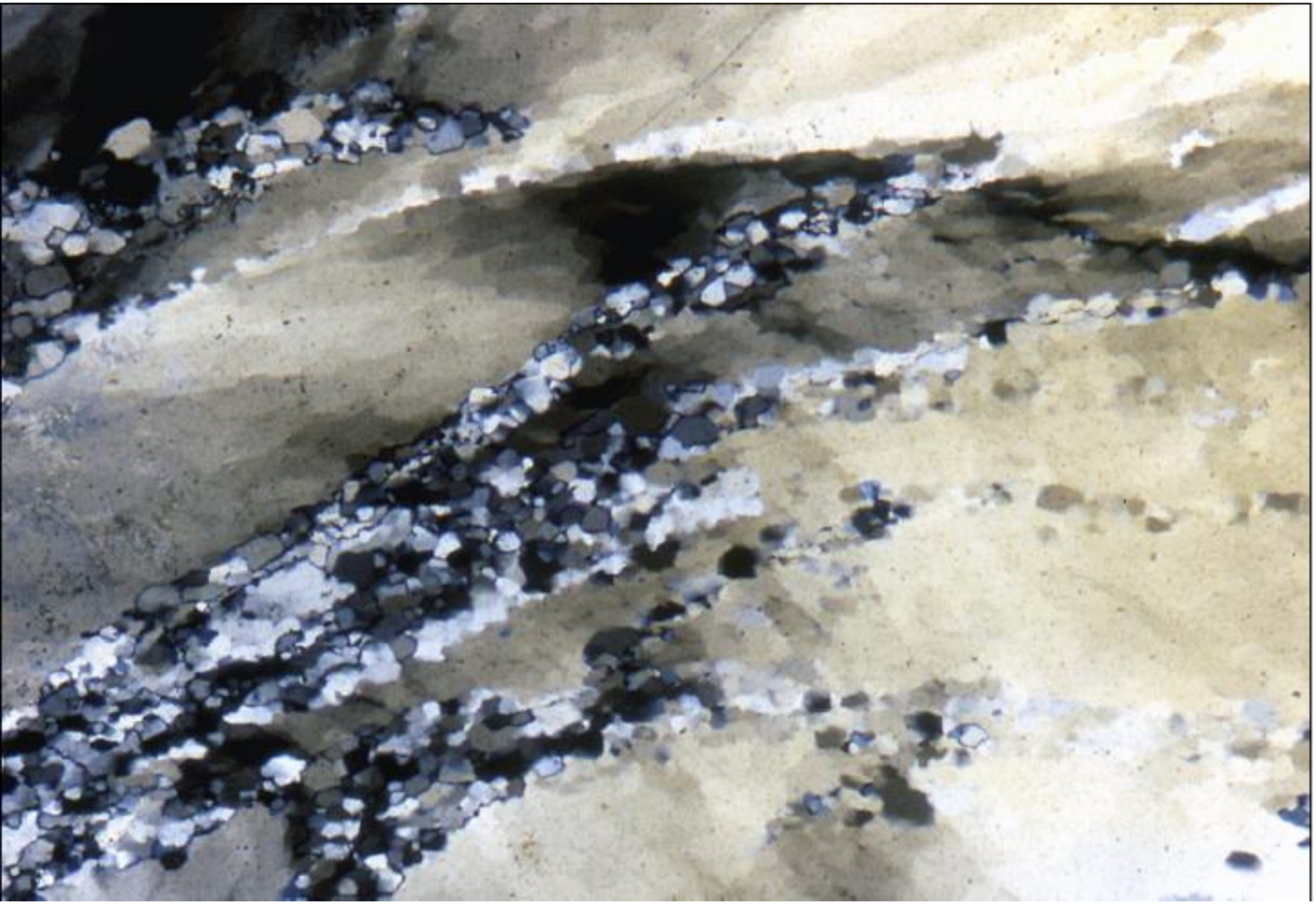
Dynamic recrystallization



Which type is it?

Trouw et al. (2010) Width of view 5mm. CPL.

Dynamic recrystallization



Which type is it?

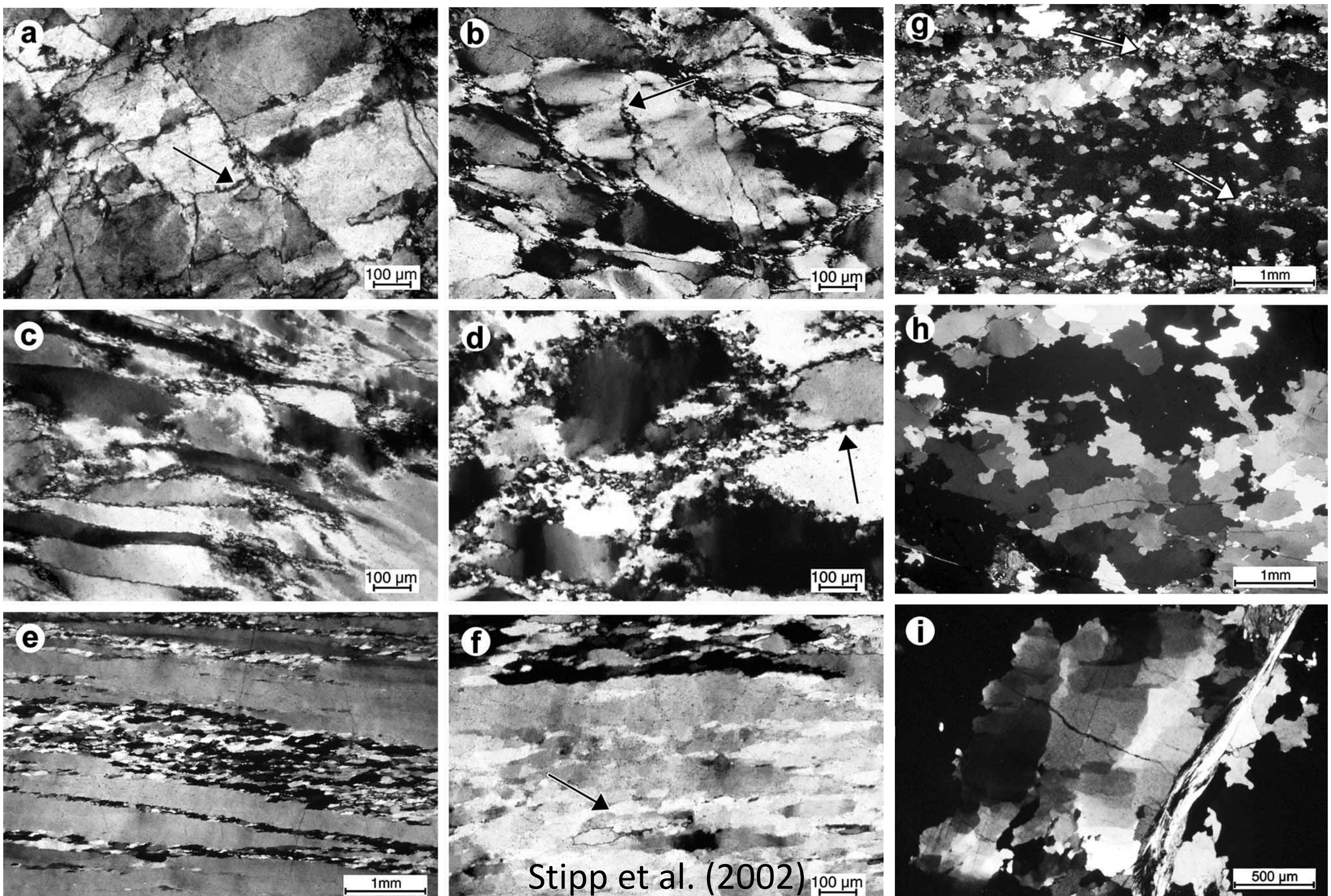
Trouw et al. (2010) Width of view 1.2mm. CPL.

Dynamic recrystallization

Which type is it?

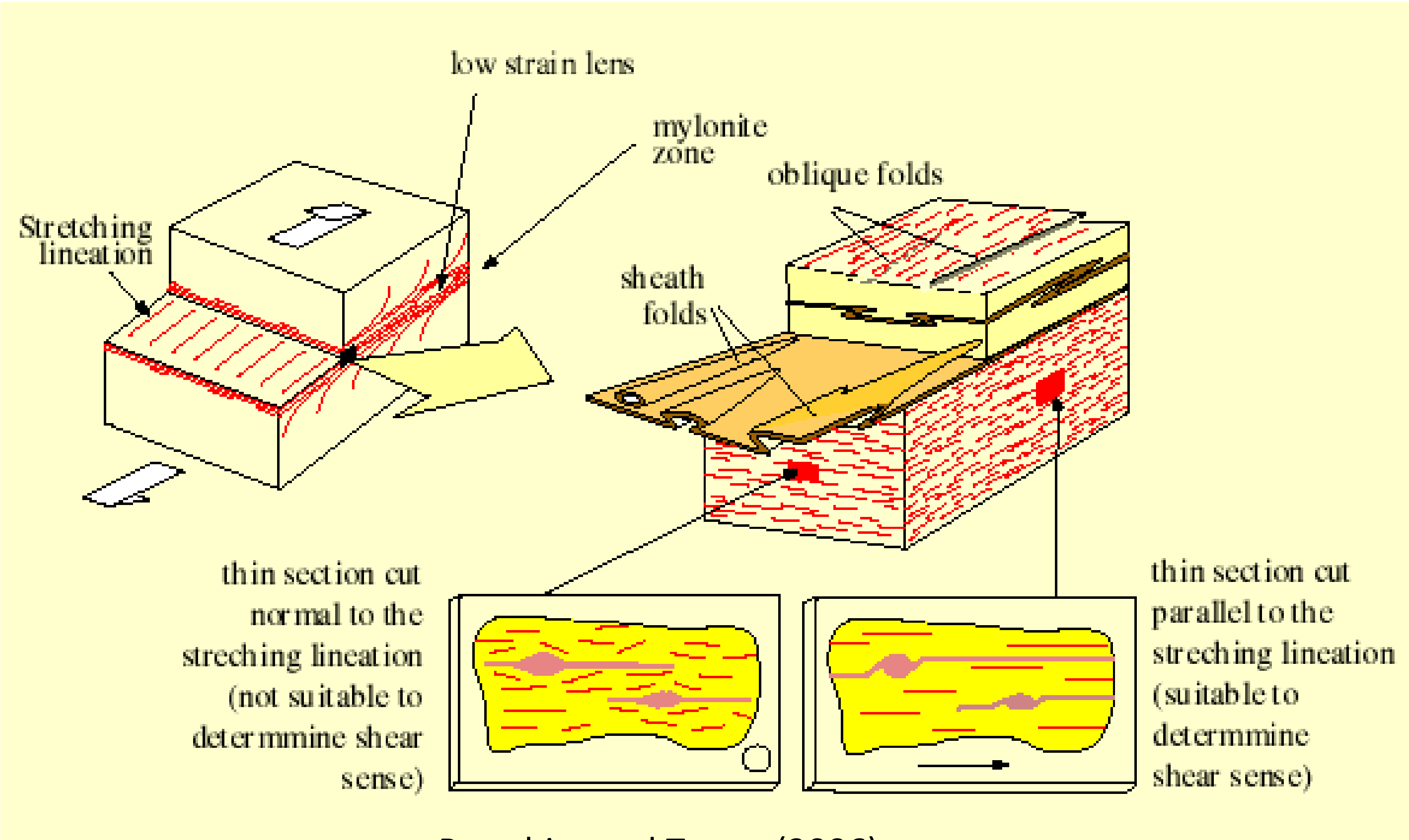
Trouw et al. (2010) Width of view 18mm. CPL.

Which type of dynamically recrystallized quartz?



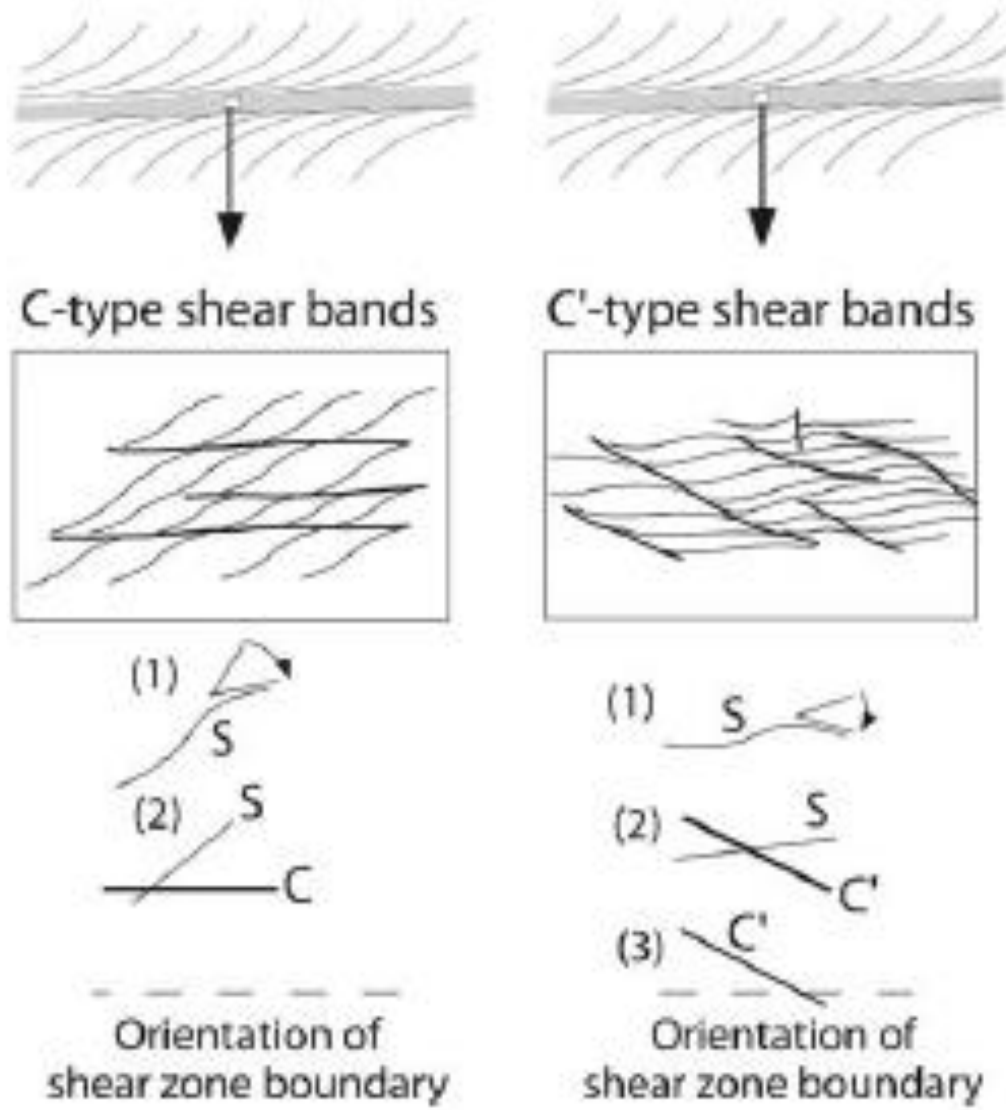
Stipp et al. (2002)

Deformation structures in shear zones



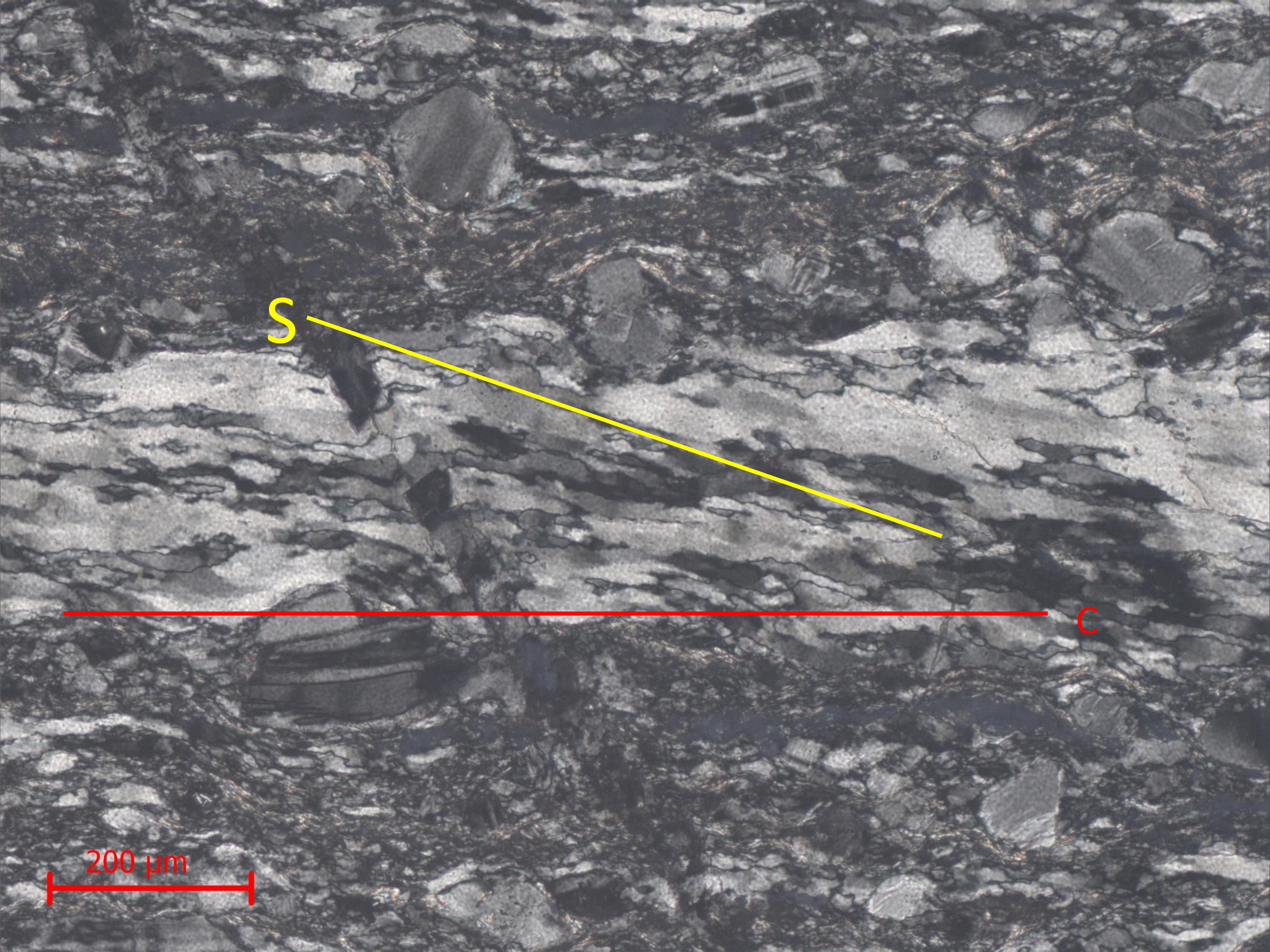
Passchier and Trouw (2006)

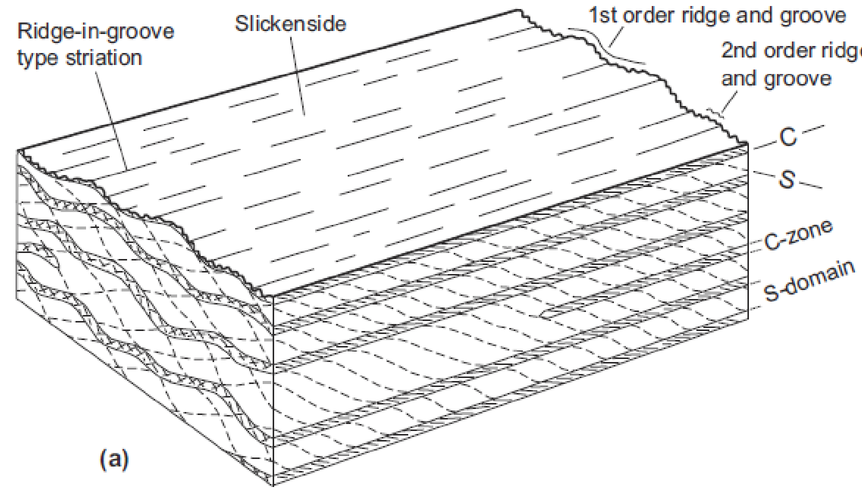
Foliations and lineations in shear zones



Dextral shear

Passchier and Trouw (2006)

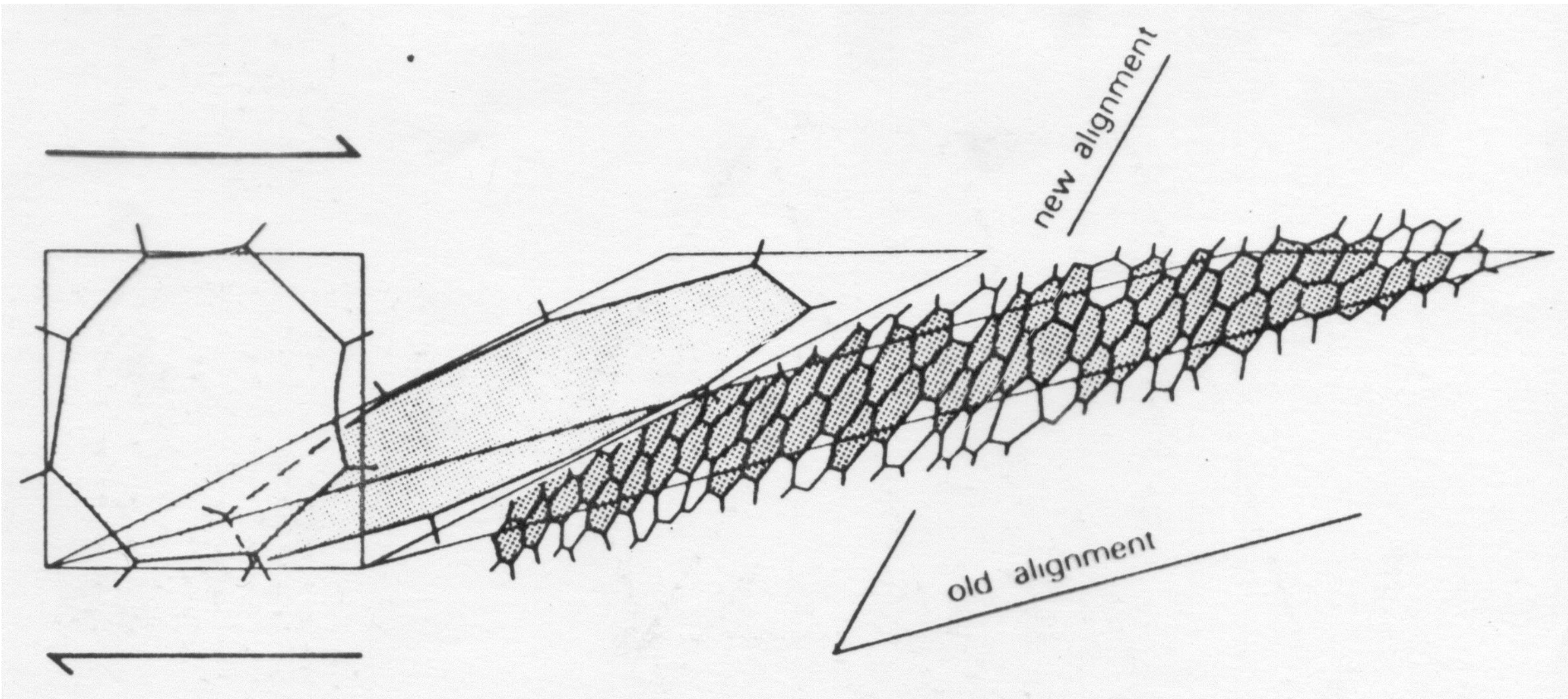

S
C
200 µm



On C-plane: Slickenside striation

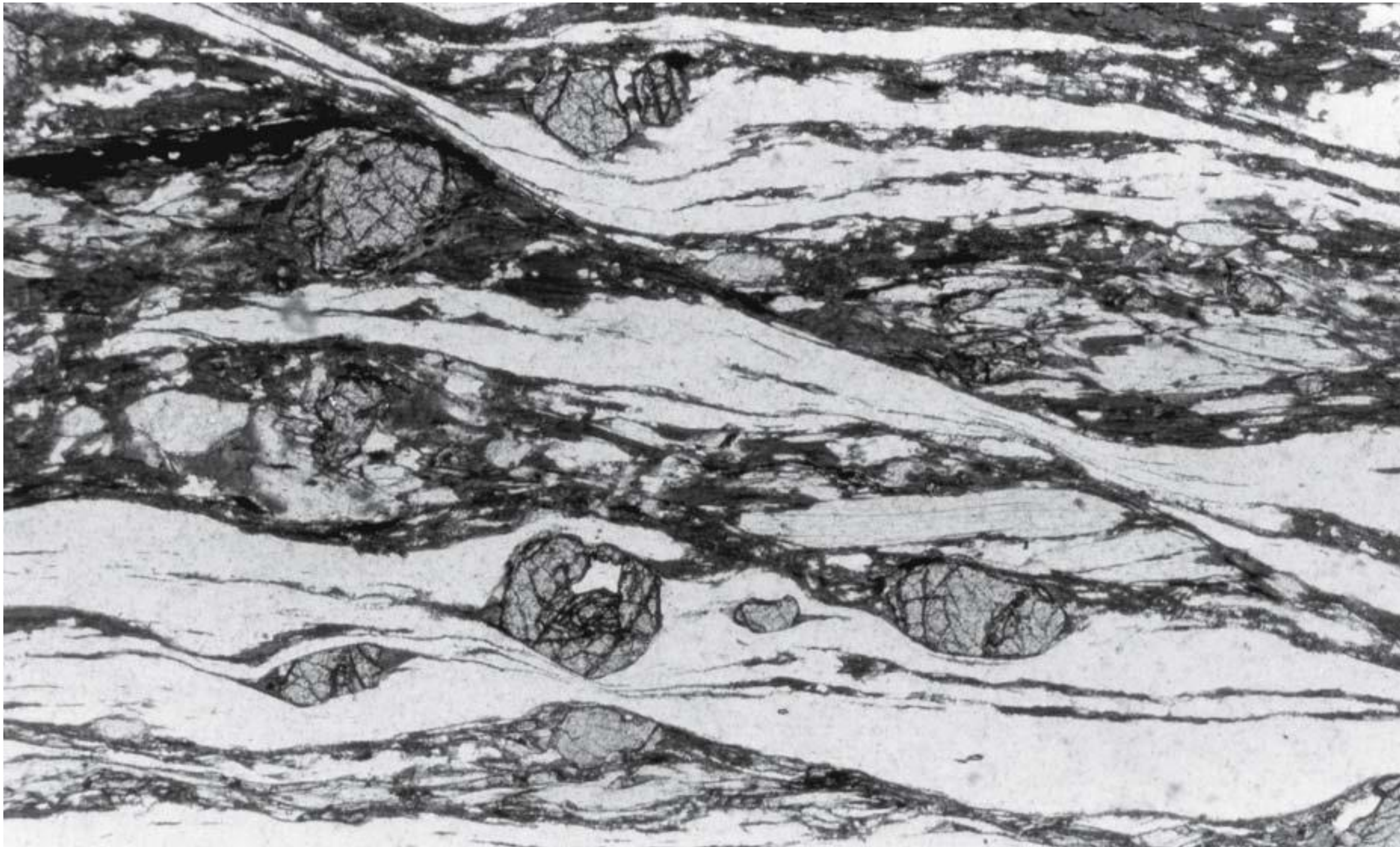
Lin et al. (2007)

Formation of steady-state foliation



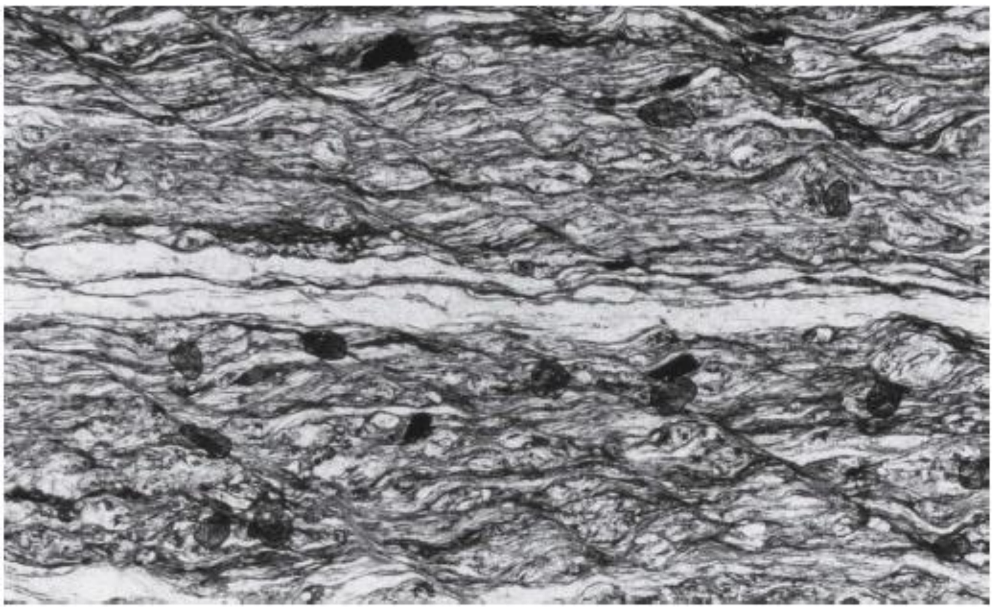
Can S foliation represent the XY plane of the finite strain ellipsoid?

Passchier and Trouw (2006)   Under PPL

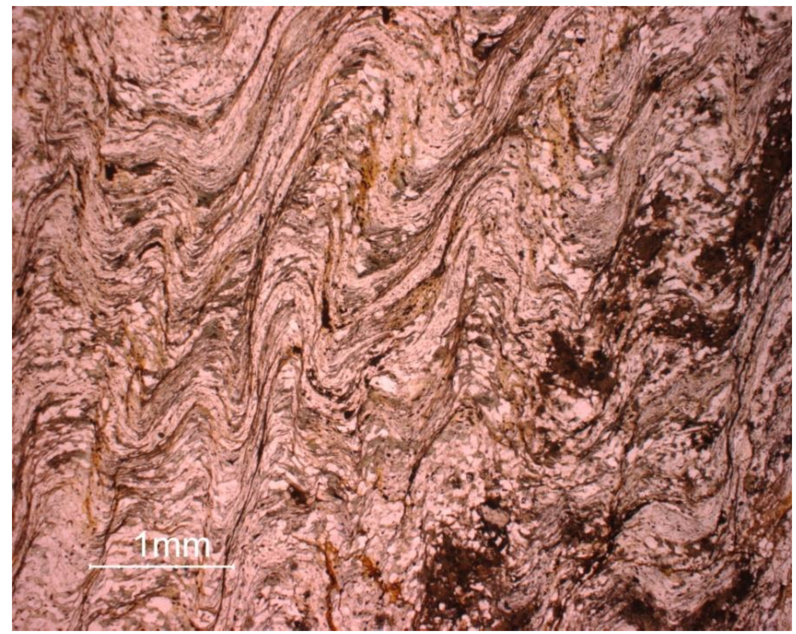


Passchier and Trouw (2006)

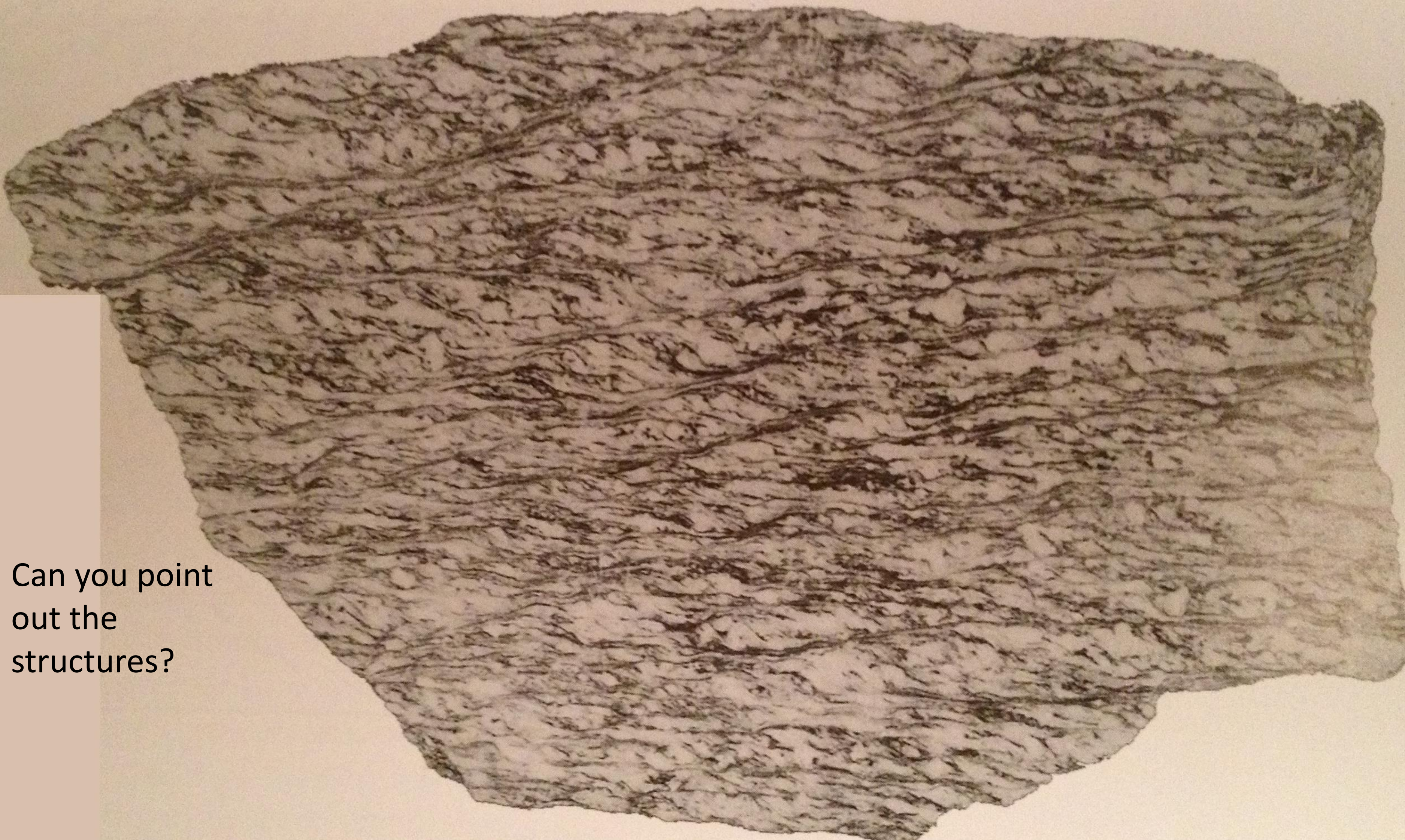
C’ and normal crenulation cleavage



Passchier and Trouw (2006)

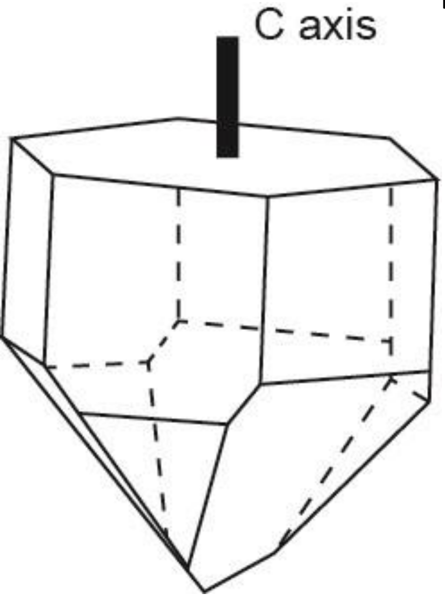


Can you point out the structures?

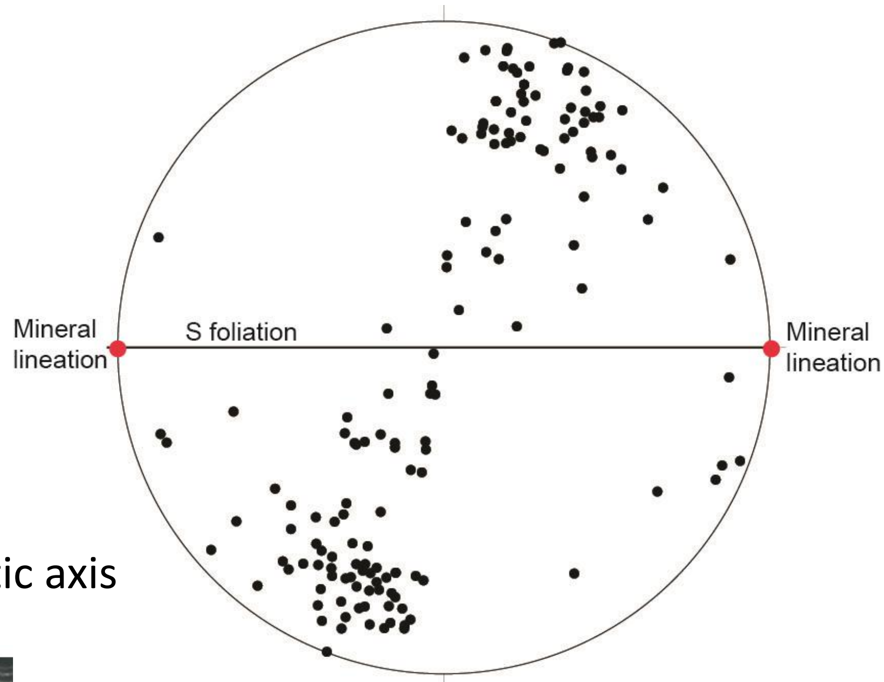


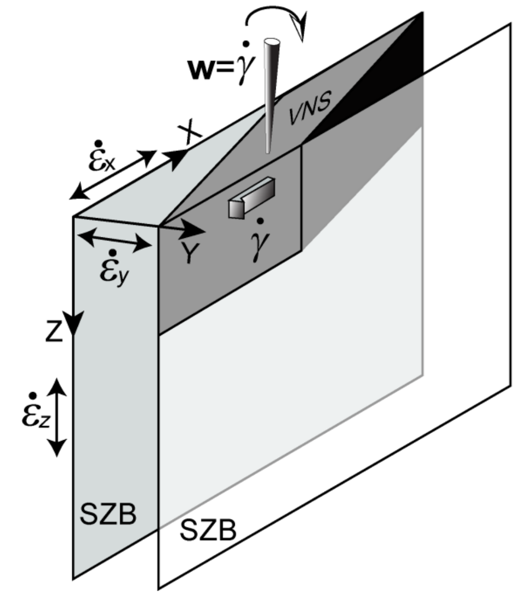
Simpson (1986)

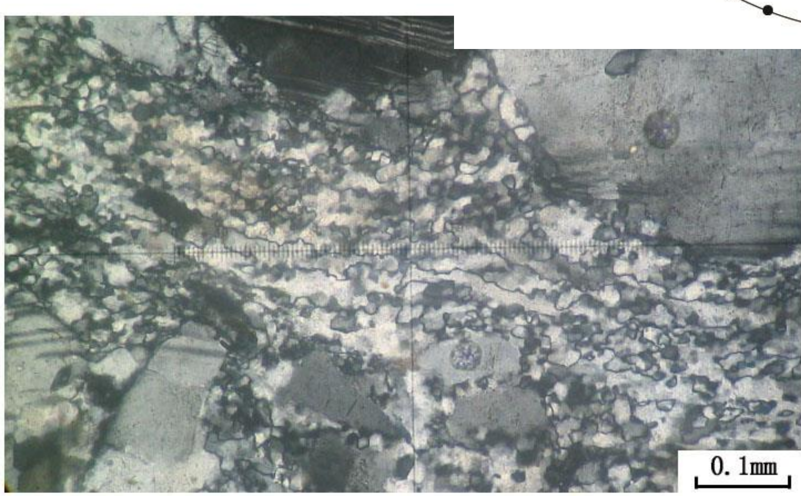
Preferred orientation of dynamic recrystallized quartz grains

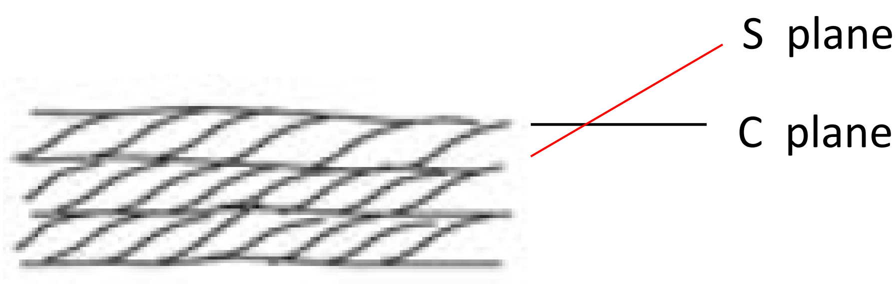


C axis: crystal axis; optic axis

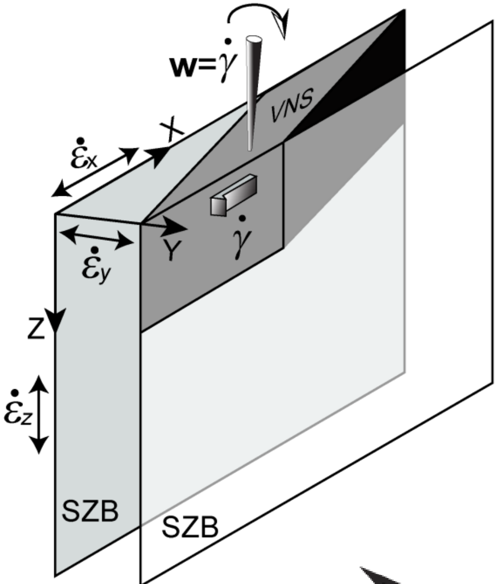




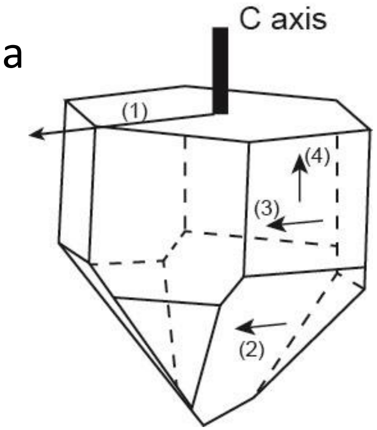




Preferred orientation of dynamic recrystallized quartz grains



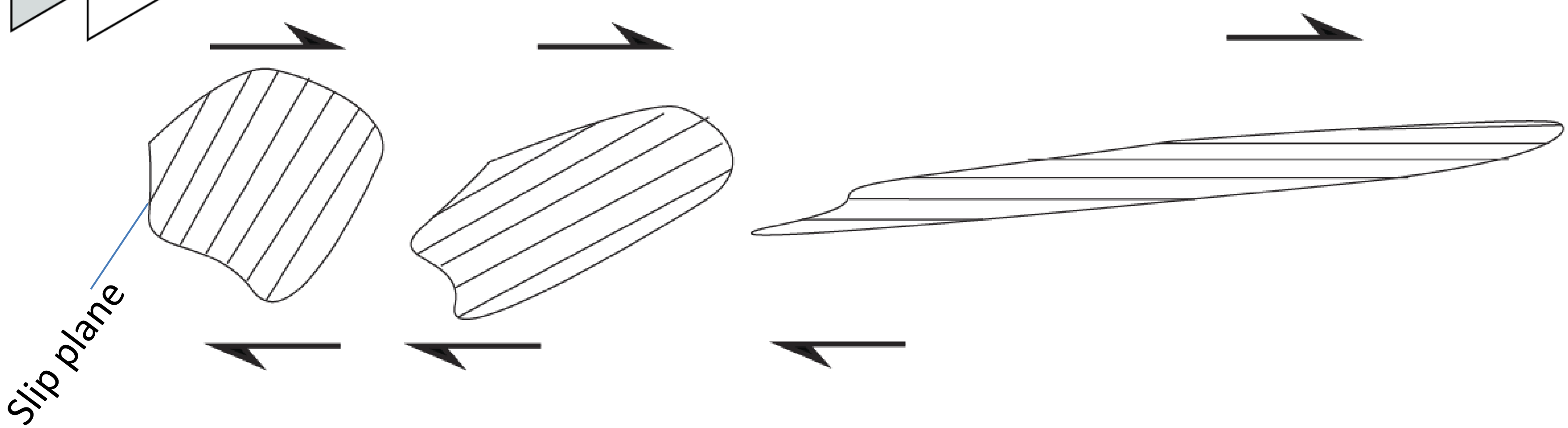
a



Slip system：

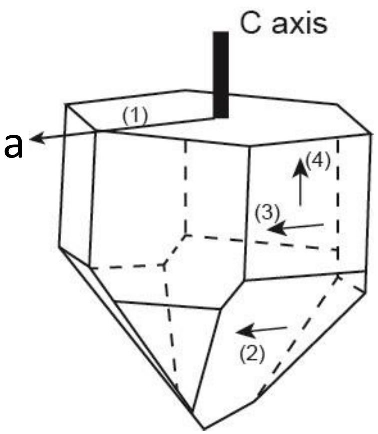
Slip plane + slip direction

(1) Basal <a> slip
(2) Rhomb <a> slip
(3) Prism <a> slip
(4) Prism <c> slip

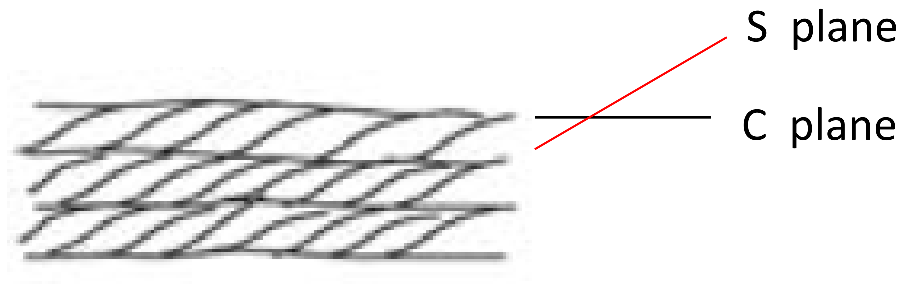


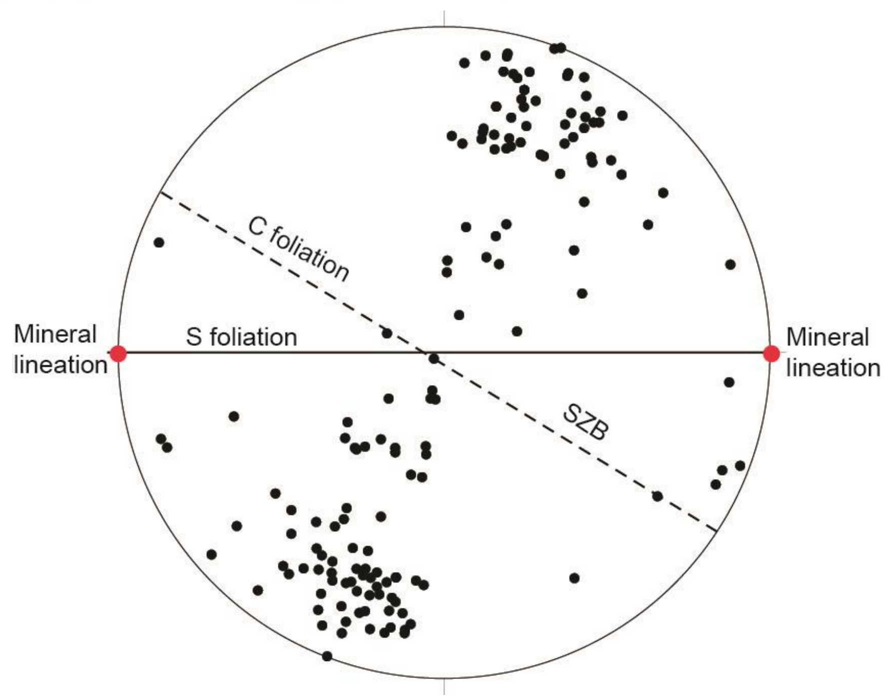
Active slip planes tend to be // SZB

Slip direction // shear direction



(1) Basal <a> slip
(2) Rhomb <a> slip
(3) Prism <a> slip
(4) Prism <c> slip



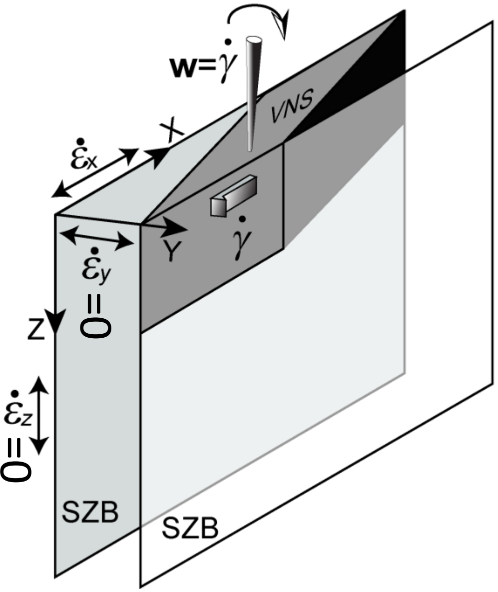


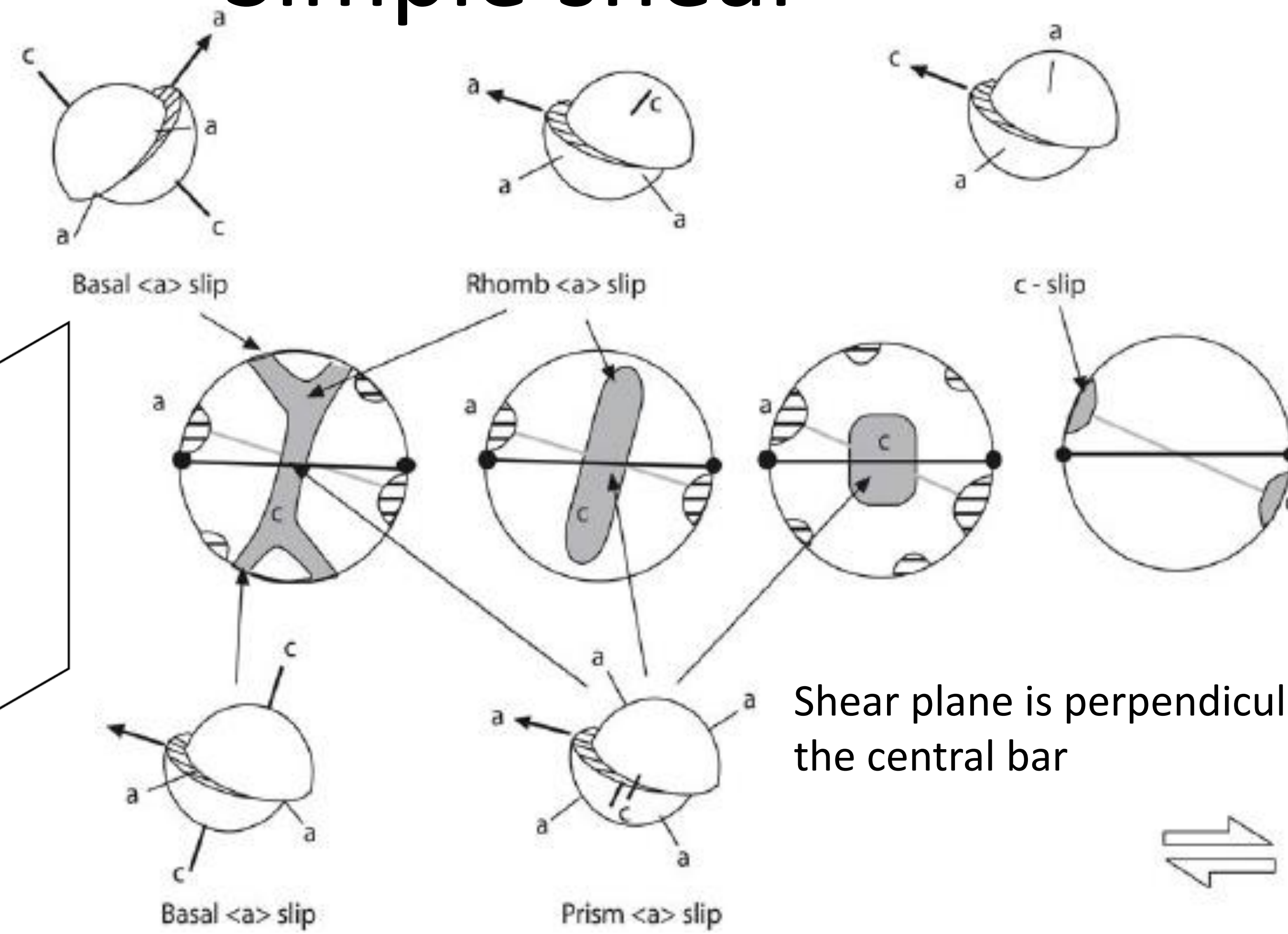
In dextral simple shear:
If slip system (1) dominates, what is the orientation for most c axes?

What if slip system (3) dominates?

(4) dominates?

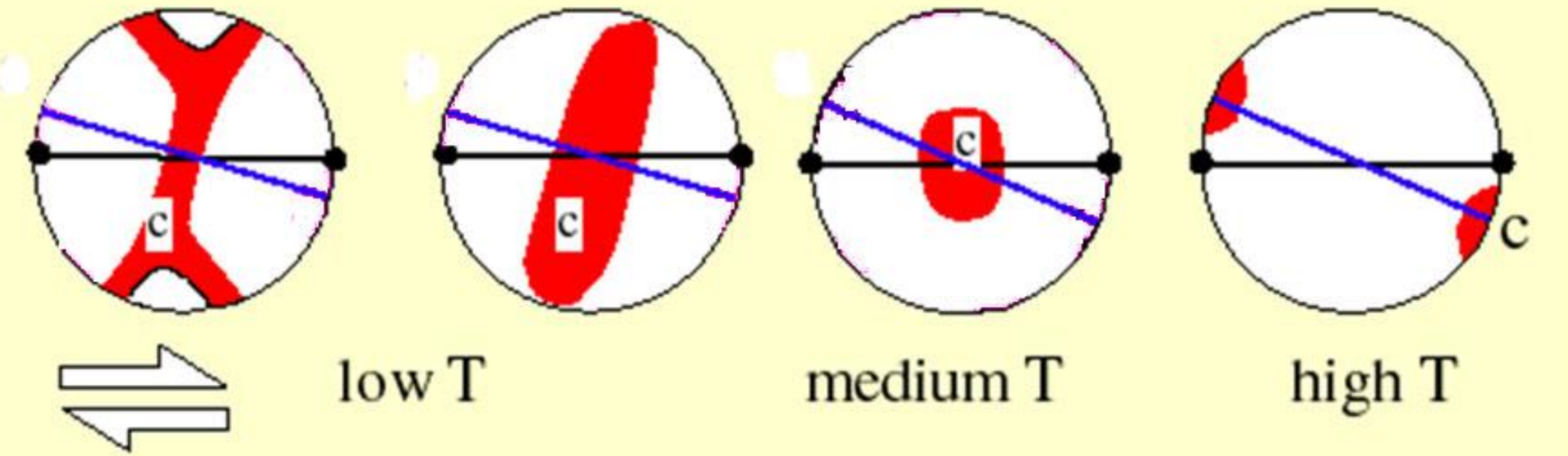
Simple shear



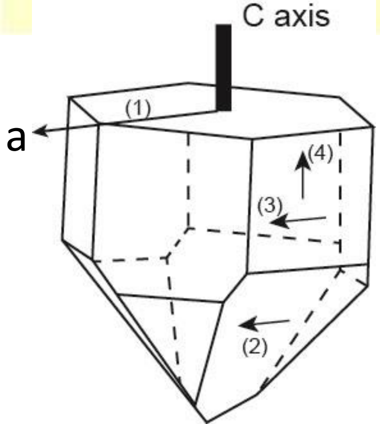


Shear plane is perpendicular to the central bar

Passchier and Trouw (2006)



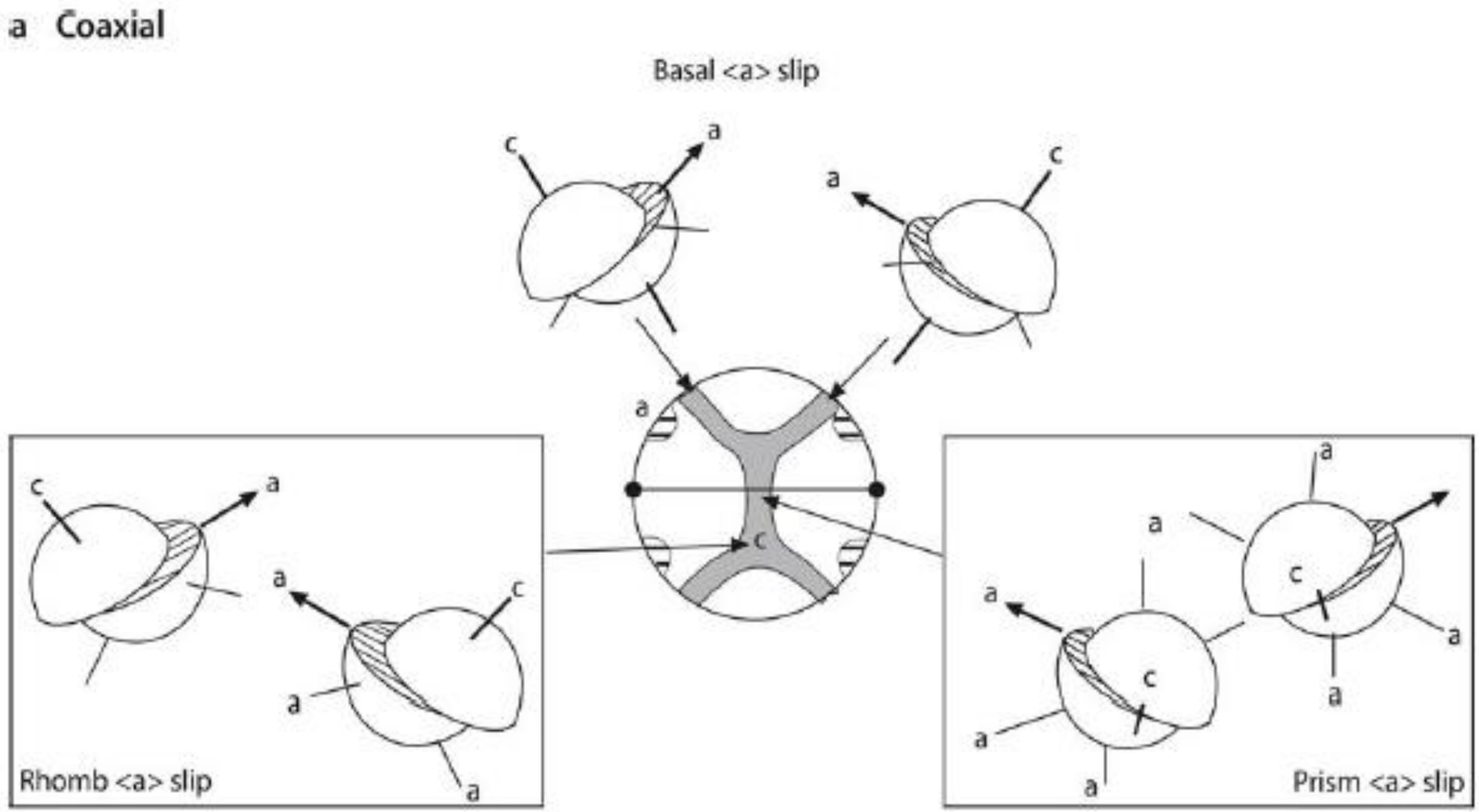
Passchier and Trouw (2006)



1. Basal <a> slip
2. Rhomb <a> slip
3. Prism <a> slip
4. Prism <c> slip

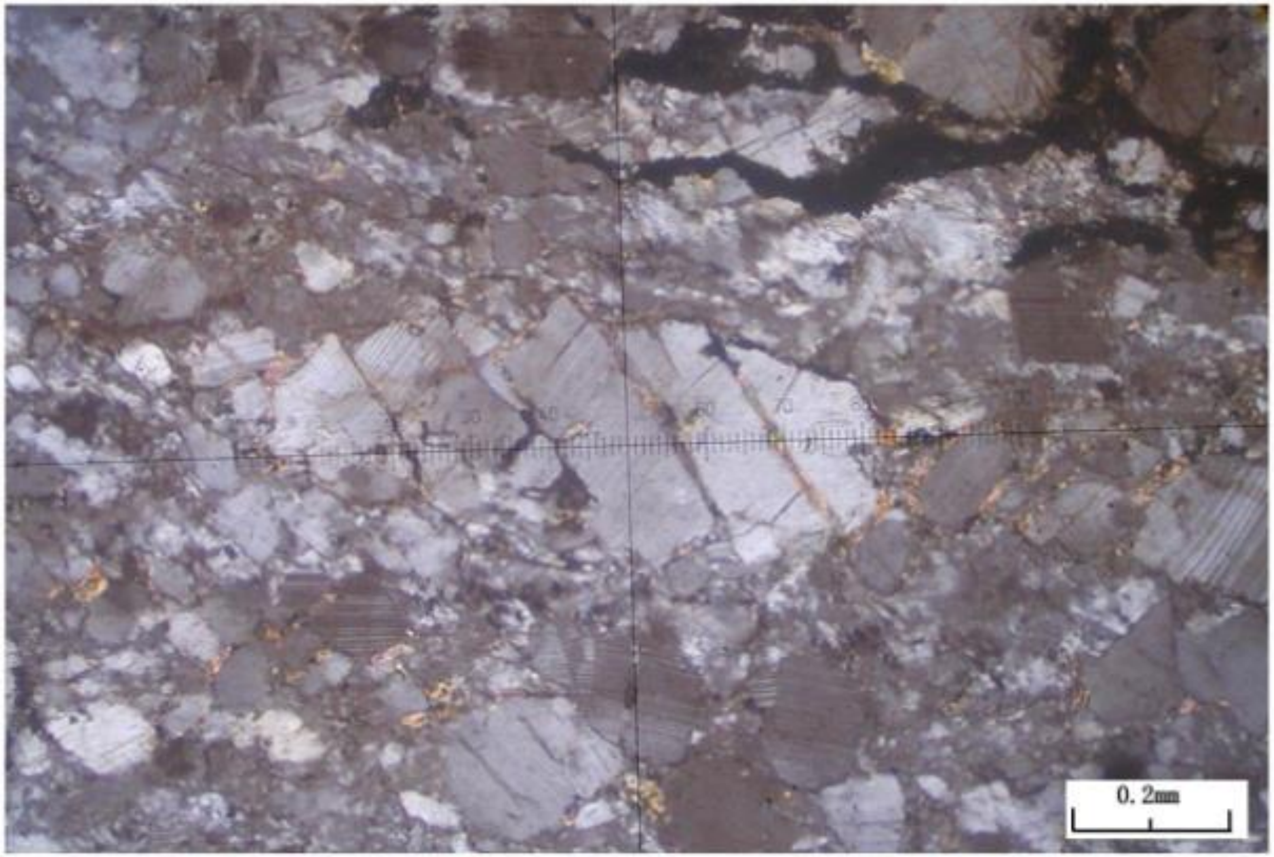
Certain Slip system is active in certain temperature range

Pure shear



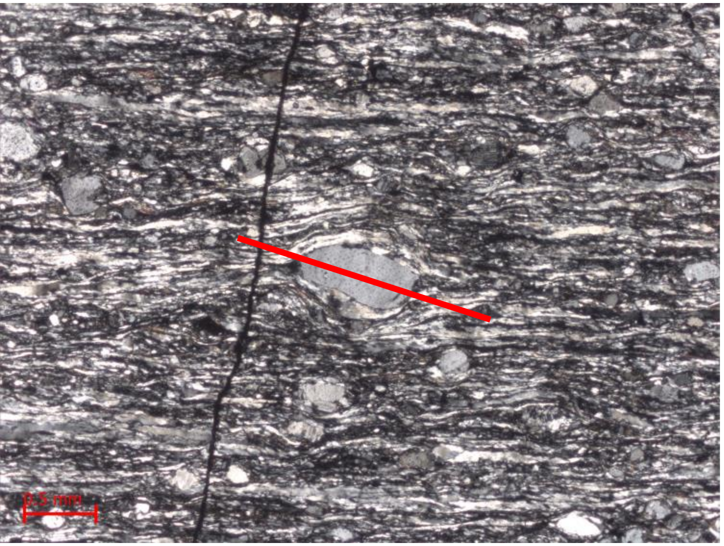
Passchier and Trouw (2006)

Porphyroclasts in shear zones

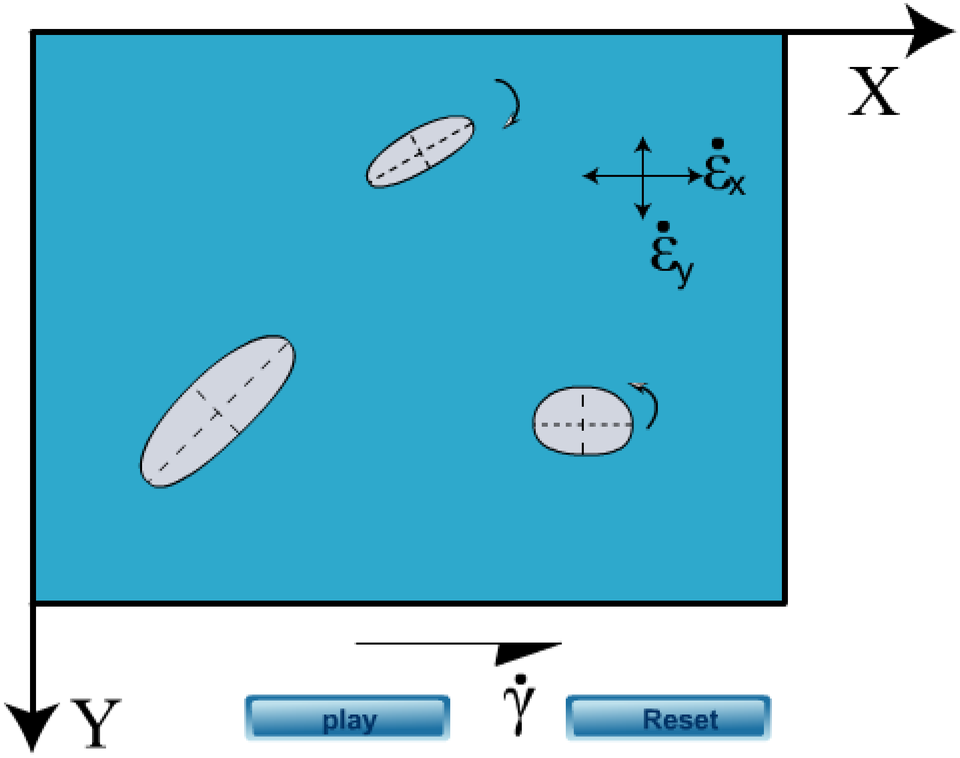


‘book-shelf’ type of structure
Here it indicates sinistral shear sense

Rigid porphyroclasts

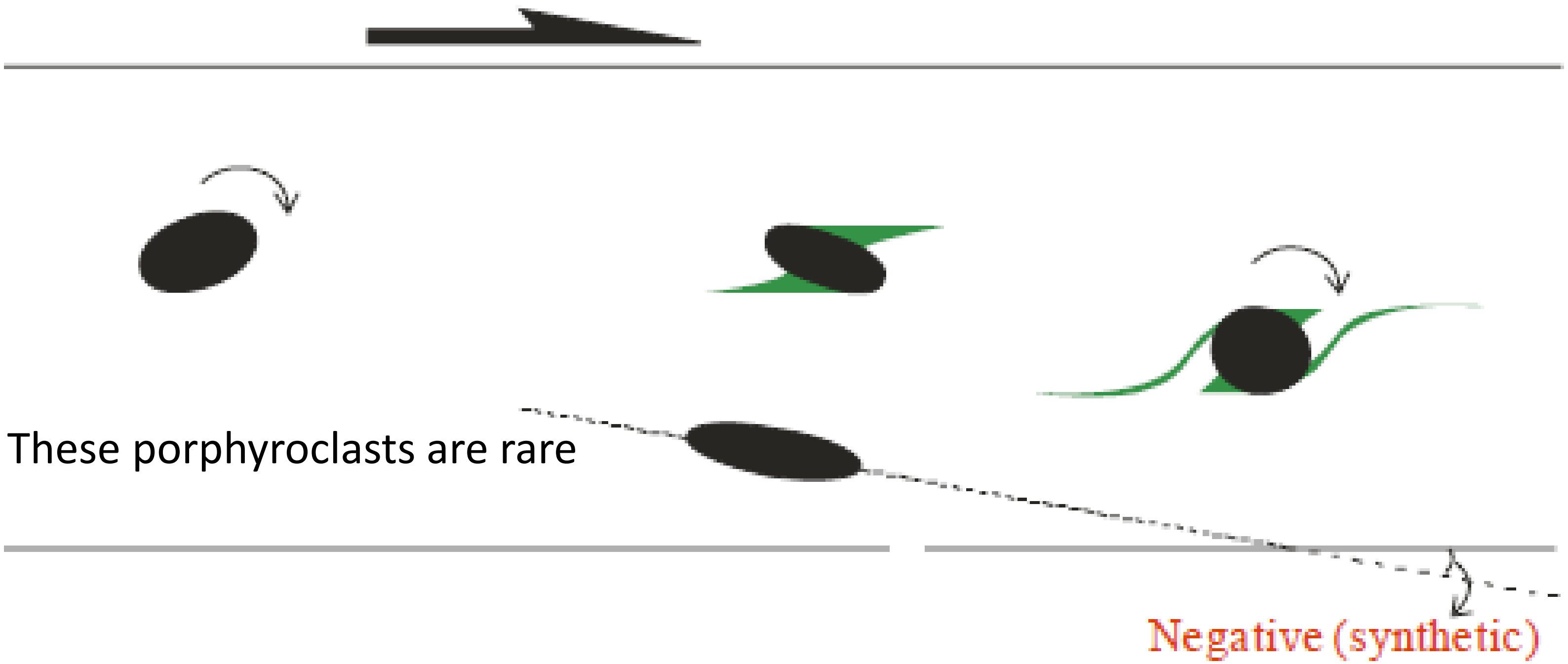


If newtonian matrix (strain rate proportional to stress)
Rigid porphyroclast follow Jeffery 's theory

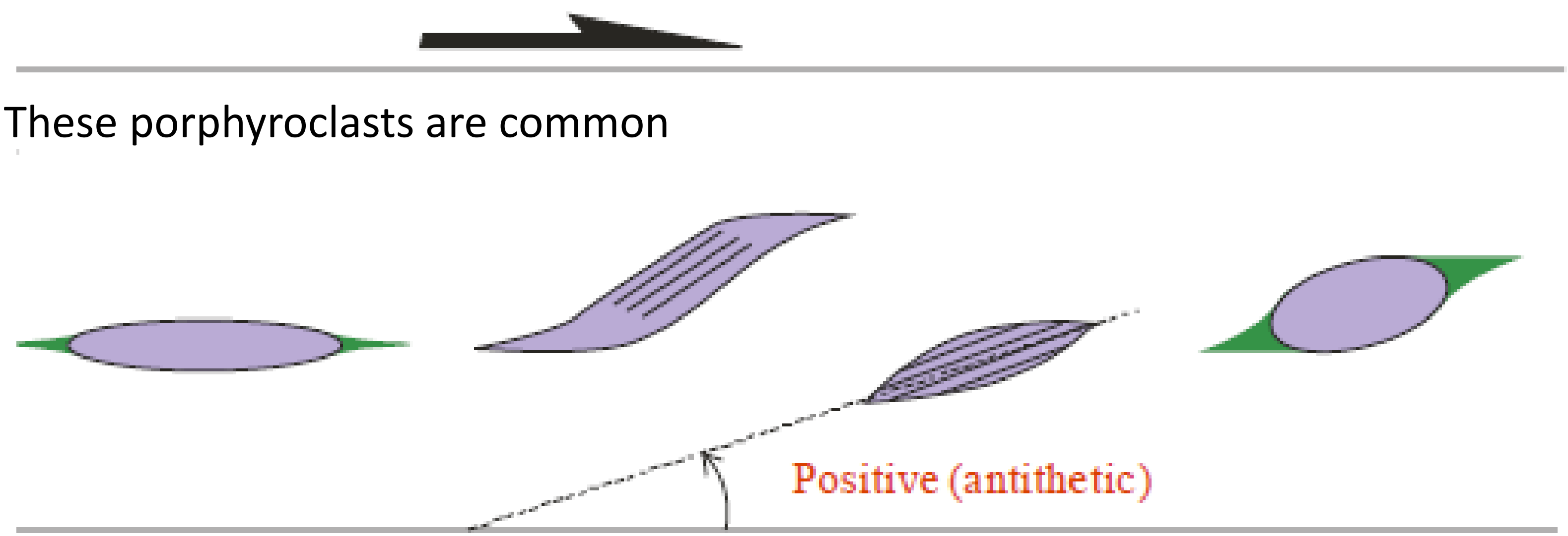


General shear
Shear sense: sinistra

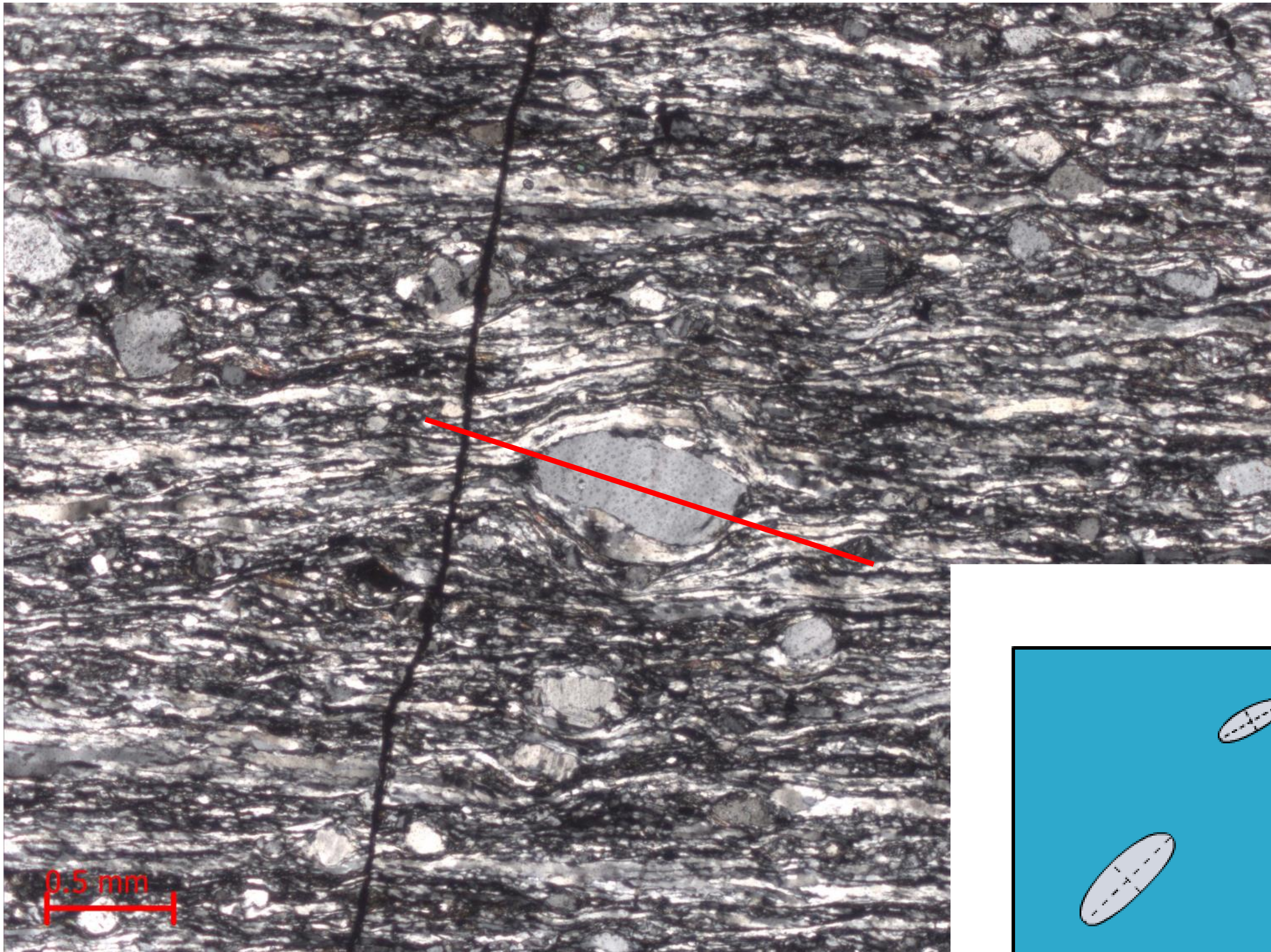
These porphyroclasts are rare



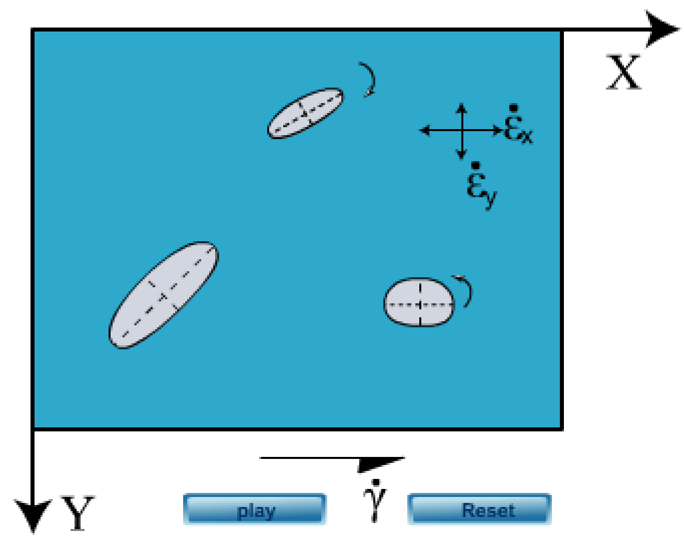
These porphyroclasts are common



Liu (2009)



Sinistral shear



Porphyroclasts in shear zones

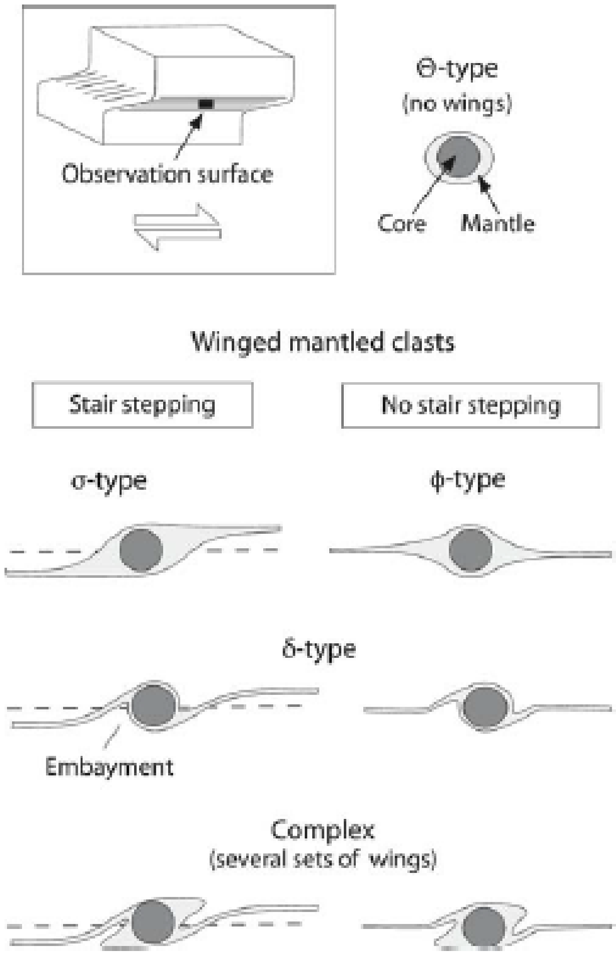


Fig. 5.21. Classification of mantled porphyroclasts. Dextral sense of shear

Passchier and Trouw (2006)

Fig. 9.2.1 Idealised sigma structure. Notice that the wings are composed of recrystallised feldspar derived from the porphyroclast.

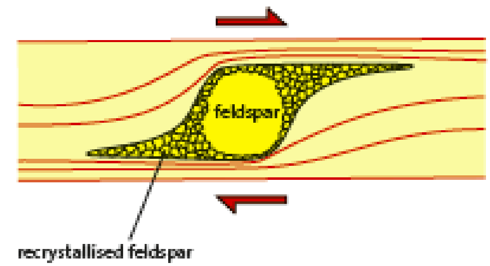
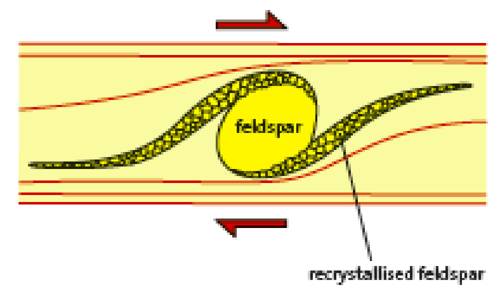
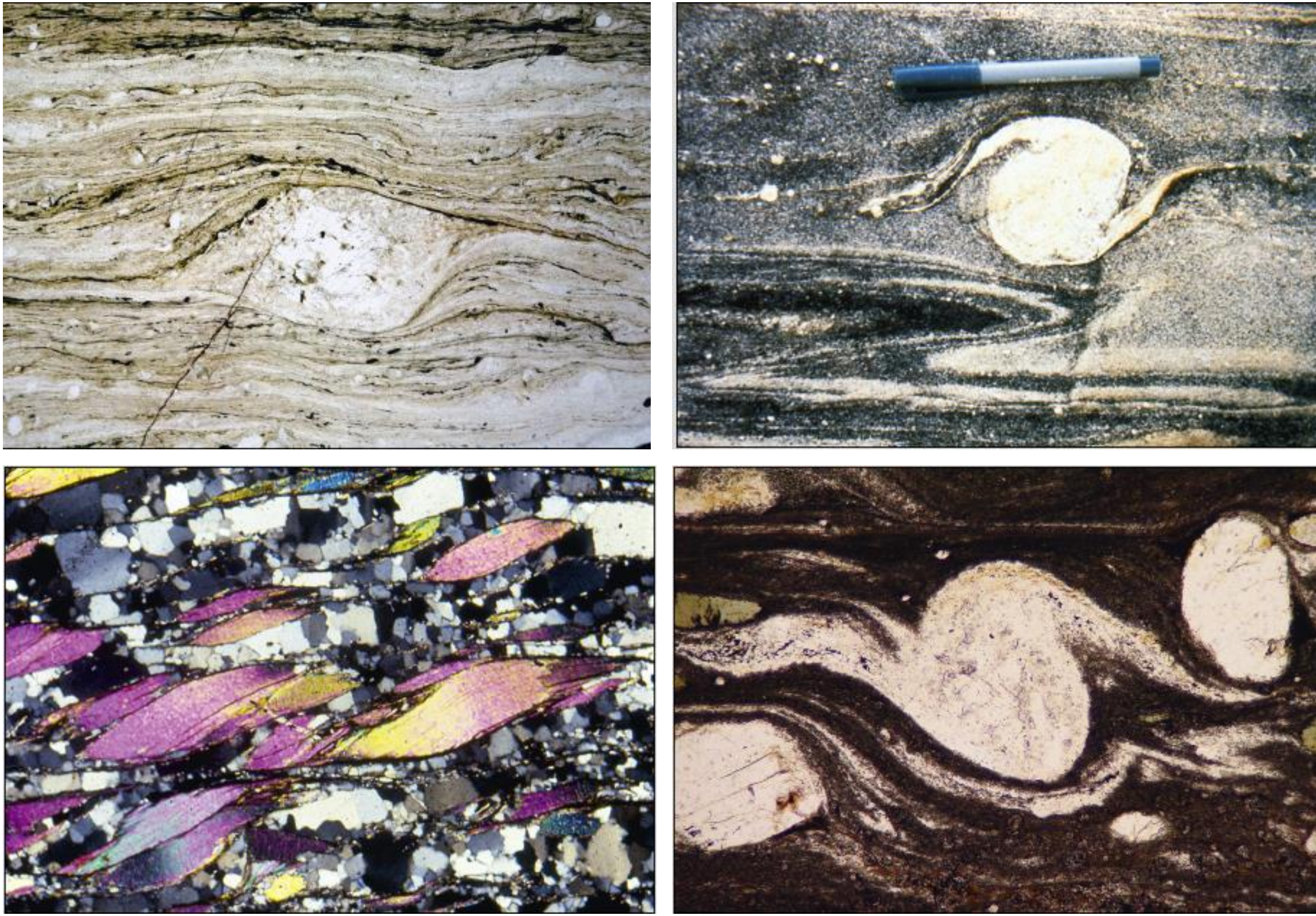


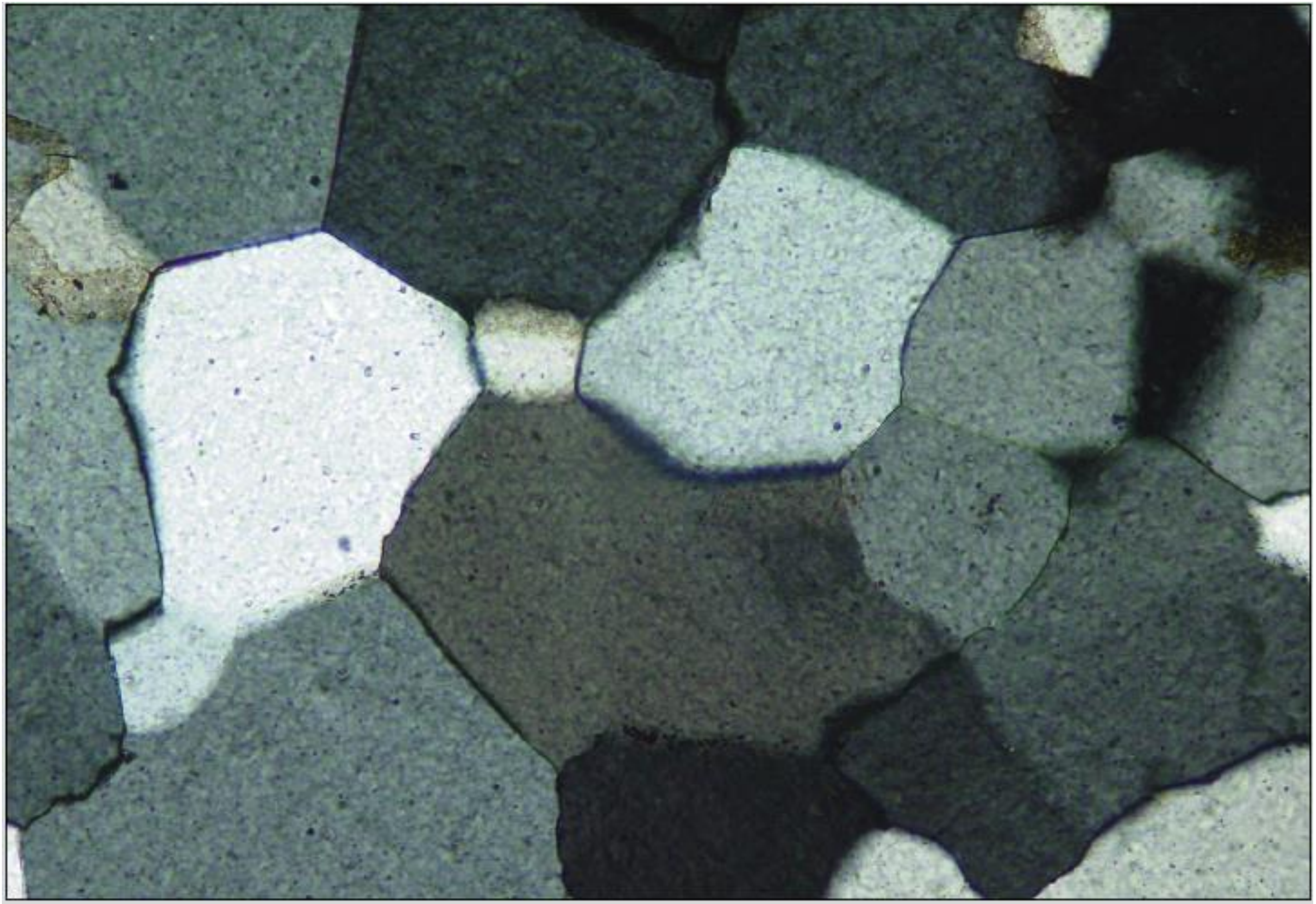
Fig. 9.2.2 Idealised delta structure.



Trouw et al. (2010)



Trouw et al. (2010)

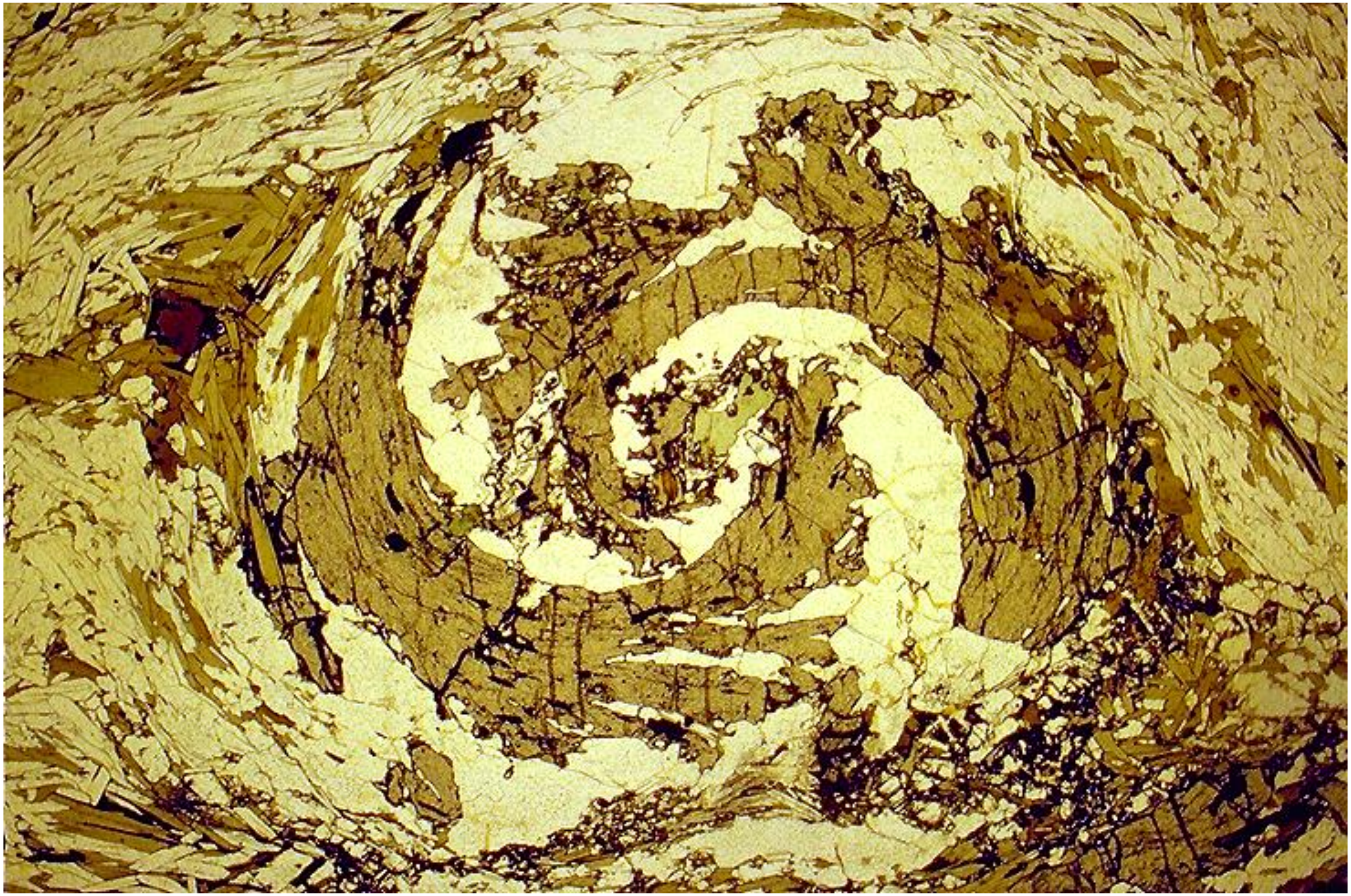


Trouw et al. (2010). Width of view 10 mm. CPL.

The straight contacts tending to make angles of 120° are the result of static readjustment after deformation.

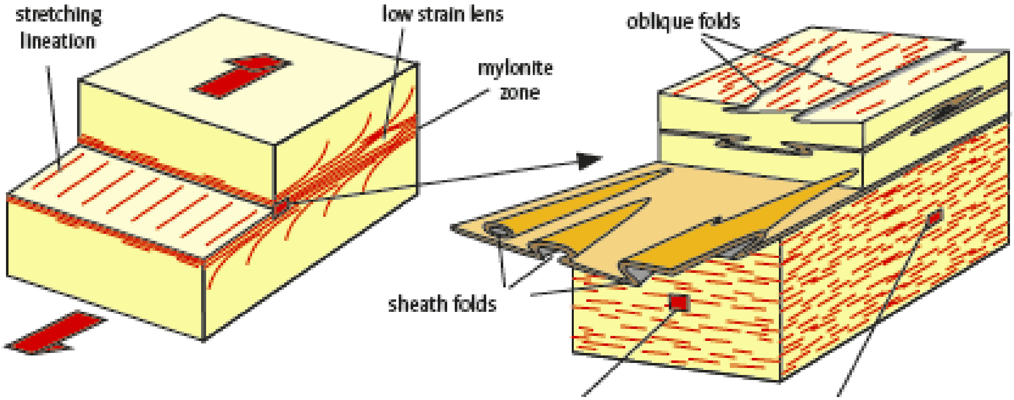
Blastomylonite (significant static recrystallization)

Porphyroblasts in shear zones

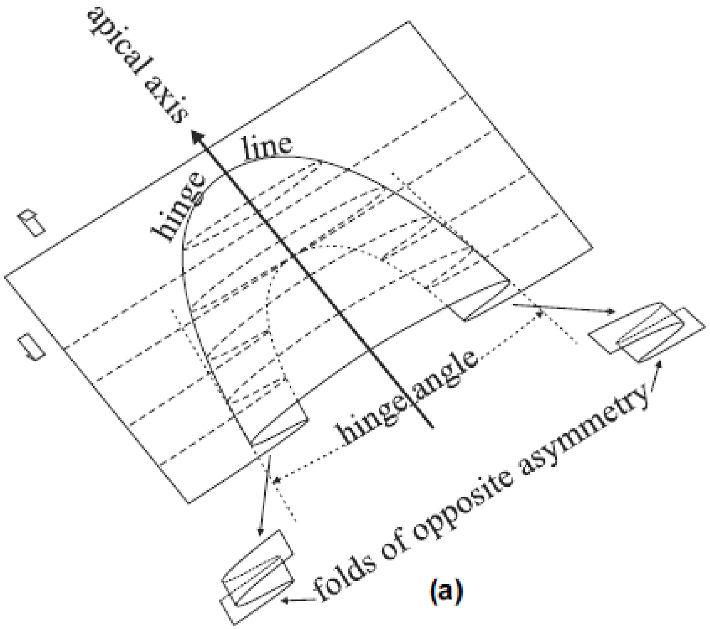


Passchier and Trouw (2006)

Folds in shear zones



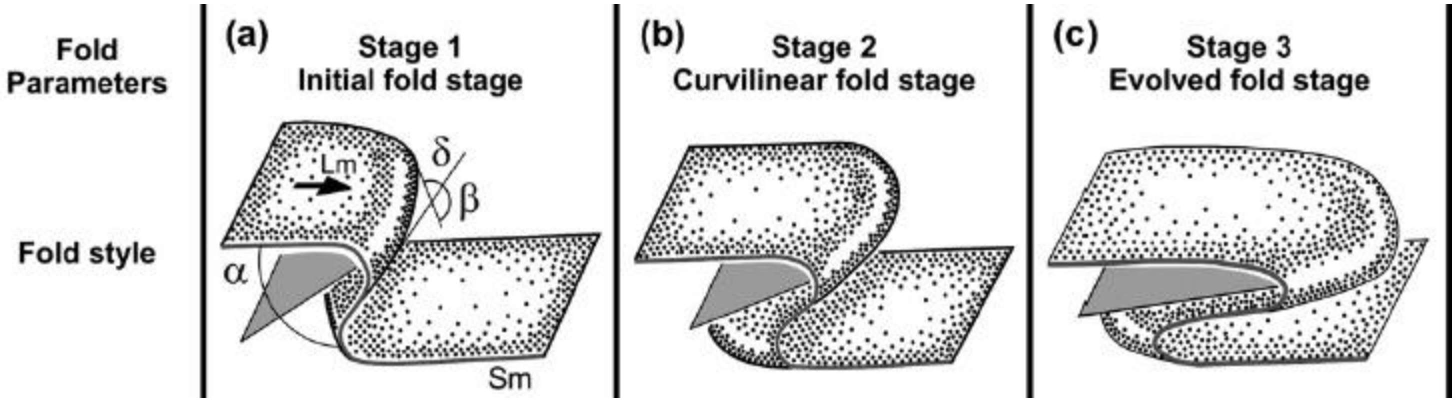
Passchier and Trouw (2006)



Kuiper et al. (2007)

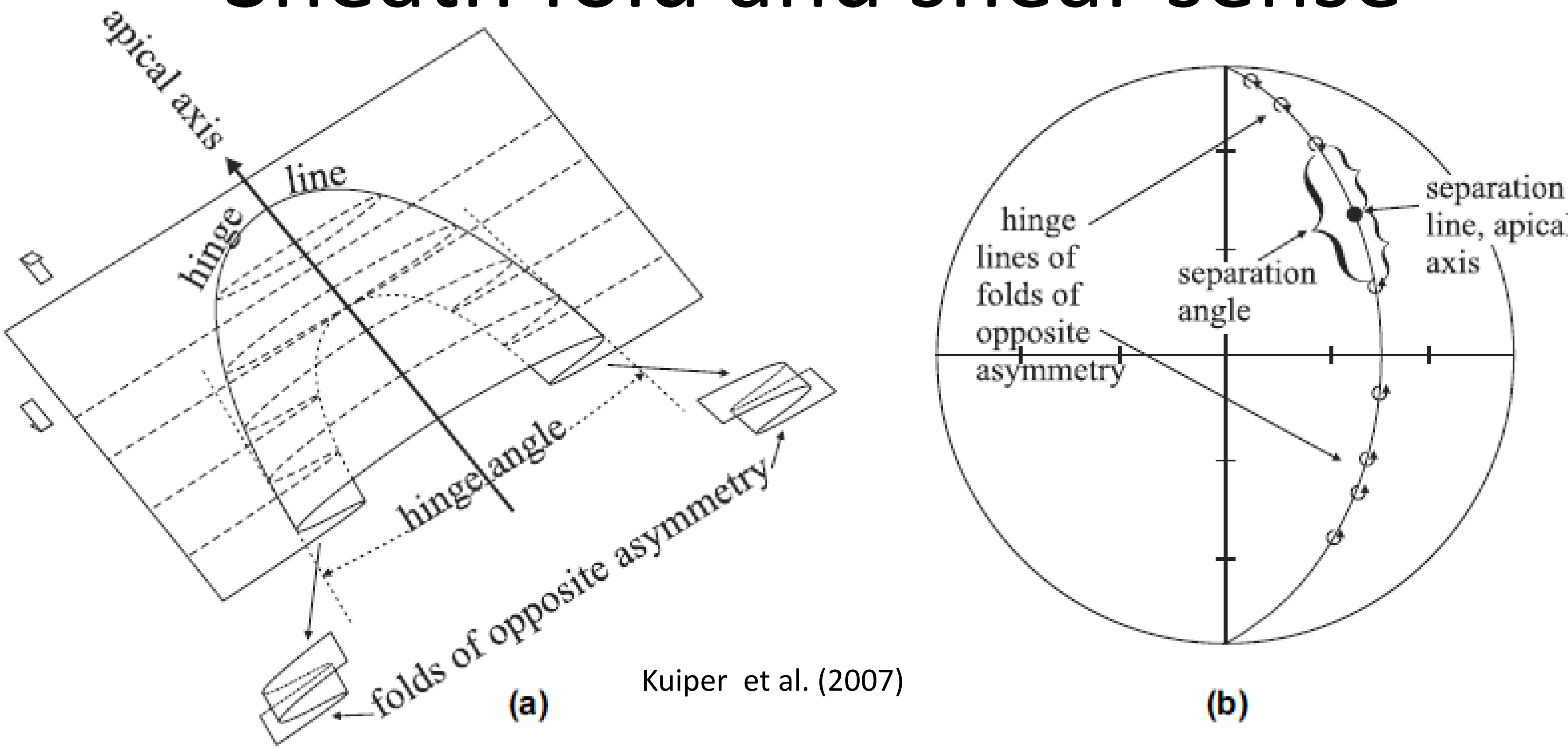

What is this deformation structure?

Folds in shear zones

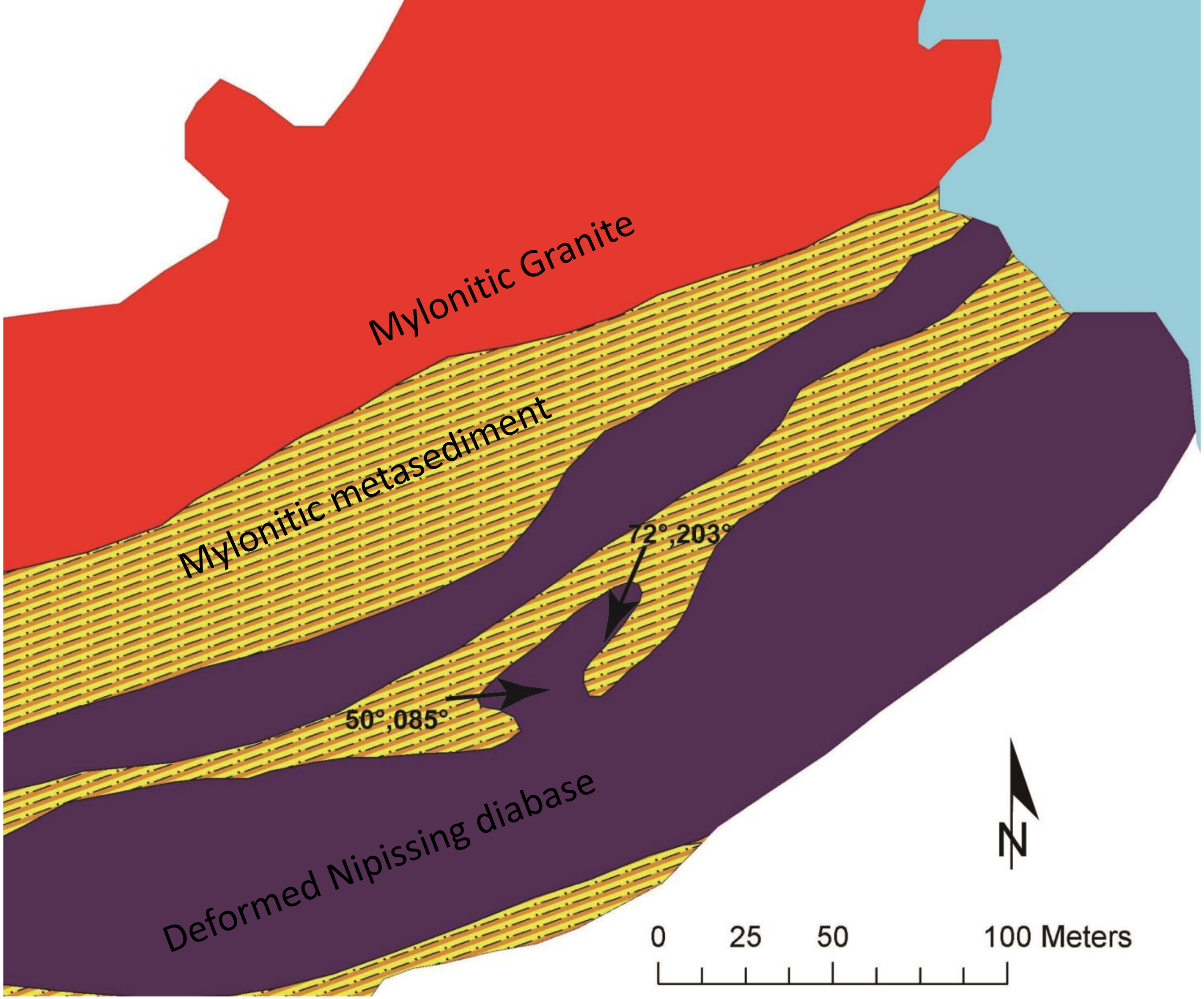


Alsop, G. I. and Carreras, J. (2007)

Sheath fold and shear sense



Kuiper et al. (2007)



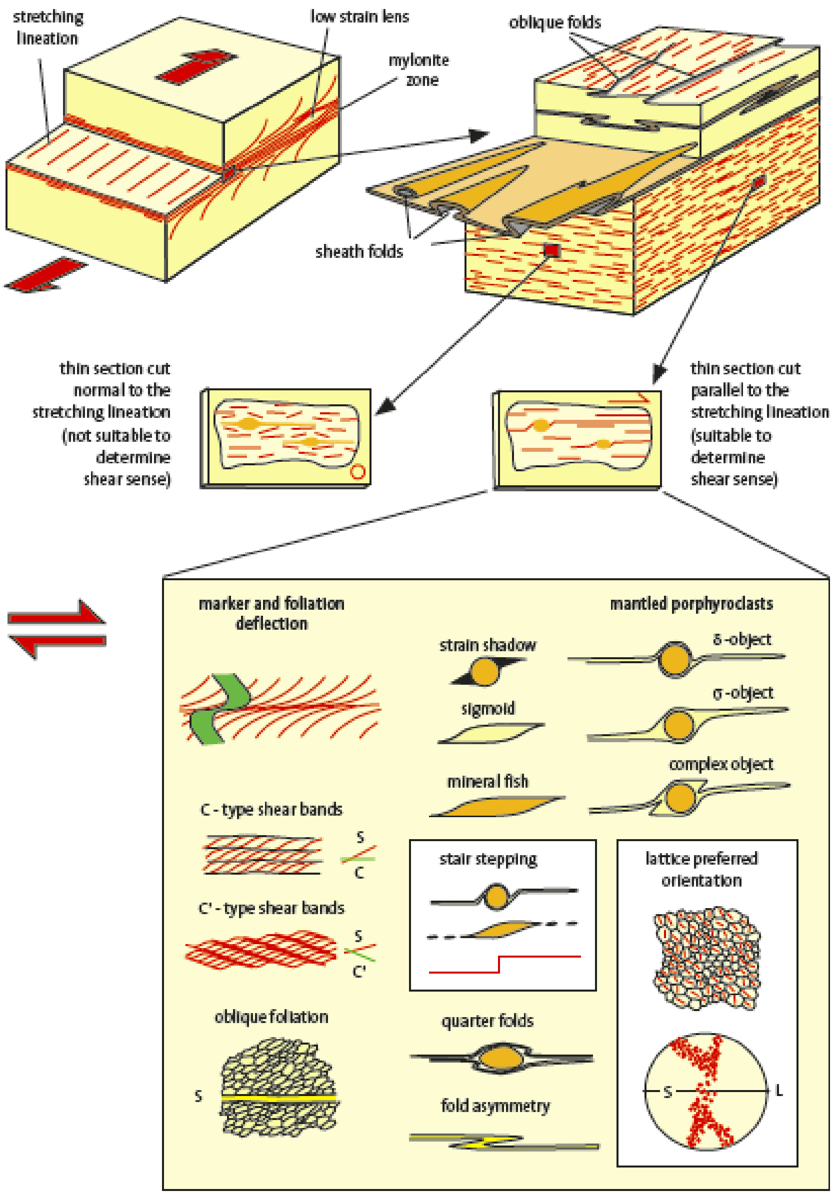
Foliations: strike NE, dip toward SE

Lineations: down dip

Shear direction is along the lineation

What is the shear sense? Think about it by yourself

Shear sense indicator summary



Passchier and Trouw (2006)